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CPP-603 UNDERWATER FUEL RECEIVING,

HANDLING, AND STORAGE

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Approval of ICPP TRIGA-Loaded Monorail Storage
Document Revisions (OPE-CPP-97-123)," dated
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DOES NOT CONTAIN UNCLASSIFIED CONTROLLED NUCLEAR INFORMATION

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1. SUMMARY

The Fuel Receiving and Storage Facility at CPP-603 was the only underwater fuel storage area at the ICPP prior to the startup of operations of the FAST Fuel Storage Area (FSA) at CPP-666 in April, 1984. As directed by the U.S. Department of Energy Idaho Operations Office (DOE-ID) and Lockheed Martin Idaho Technologies Company (LMITCO) management, the current mission of CPP-603 is to prepare for decontamination and decommissioning (D&D) by removing all fuel from storage by December 31, 2000. CPP-603 shall receive fuel for storage only if prior approval is received from DOE-ID and LMITCO management. To date (1996) all fuel has been transferred from the north and middle storage basins to CPP-666 and the south storage basin. The monorail system in the north and middle storage basins shall only be used for fuel handling and storage if fuel is found on the basin floor during D&D and only if prior approval is received from the DOE-ID and LMITCO management. The CPP-603 facility consists of three interconnected water-filled storage basins (north, middle, and south) and two crane bays (along the south and west sides of the building) with associated fuel transfer stations. The basins are supplied with water from the reverse osmosis demineralization system. A concrete driveway runs through the west crane bay (north-south direction), and a railroad spur and driveway run through the south bay (east-west direction).

Metallic-clad (aluminum, zirconium, or stainless steel) fuels and other miscellaneous types of fuel are received, handled and stored under water at this facility. The handling and dry storage of graphite-based fuels in CPP-603 are discussed separately in PSD Section 4.12. The processes for treating and maintaining the quality of the water fed to and in the fuel storage basins include filtration, ion exchange, chloride removal, reverse osmosis demineralization, and ultraviolet light sterilization. A block diagram of both the fuel handling and water treatment processes, identifying the individual steps, is shown in Figure 1.

The wastes generated at this facility consist of aqueous and solid wastes. The disposal method used is determined by the nature of the liquid or solid waste, e.g., radioactive or nonradioactive. There are
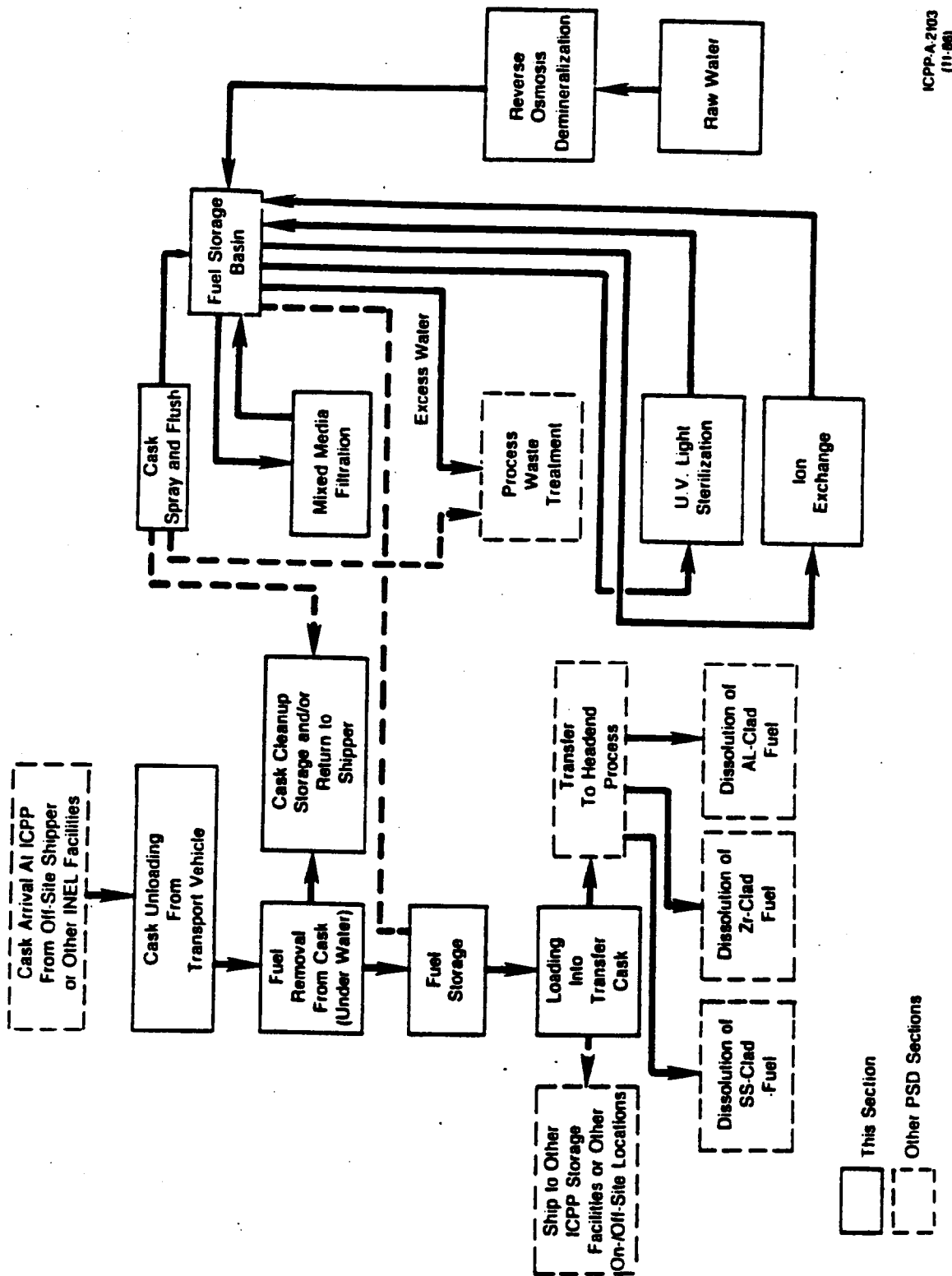
Figure 1. Block Diagram of CPP-603 Fuel Handling and Water Treatment Processes

no gaseous wastes generated at CPP-603, except for cask and process vessel venting through a HEPA filter.

The hazards to operating personnel during normal operation include exposure to low-level radiation fields, routine industrial hazards, and chemical handling. These hazards are mitigated by equipment design, use of protective clothing and equipment, adherence to operating procedures and safety training. Normal operation of this facility does not result in release of significant quantities of radioactivity to the environment or radiation doses to the public. The radiation doses to operating personnel are not significant, the nominal dose arising from normal operations (by 1988) is 10 mrem (penetrating and skin dose) per month per individual.

The postulated abnormal occurrences associated with operation of this facility are loss of containment (on a single fuel piece and a on facility-wide scale), loss of shielding, and loss of configuration control relative to fuel arrays. The potential consequences of these occurrences include excessive radiation doses to personnel, release of radioactivity to the environment, and criticality. The maximum postulated accident for this facility is a criticality accident that results in fission product releases from the facility. The consequences of that maximum postulated accident are (1) an inhalation committed dose equivalent (CDE) to an individual at the site boundary of 0.002 rem (whole body), 0.005 rem (thyroid), 0.007 rem (bone surface) and 0.13 rem (lung), and (2) a CDE to operating personnel of 0.4 rem (whole body), 1 rem (thyroid), 14 rem (bone surface) and 25 rem (lung). The total dose (committed effective dose equivalent (CEDE) plus penetrating DE) at the site boundary is 0.016 rem for the MPA, and the total dose to an operator is 3.1 rem assuming 1 minute evacuation time.

In addition to the consequences of the postulated abnormal occurrences, continued operation of this aging facility poses some unique potential hazards arising from long-term storage of severely deteriorated fuel, deteriorating storage equipment (e.g., racks) and from the probable inability of the facility to withstand a large seismic event.

With respect to the earthquake issue, it has been concluded that the facility could be severely damaged by a major earthquake. The basin walls and floor are likely to crack and leak, but the walls of the basin are not expected to fall in. Collapse of the building superstructure, failure of the monorail fuel storage systems, and loss of containment in the water treatment areas are the possible effects of a large earthquake on this facility. The magnitude of the earthquake necessary to produce these effects has not been determined; however, the probability that such an earthquake would occur within the next few years is very low. As stated earlier, the current plan is to remove all stored fuel from CPP-603.

In any case, the consequences of gross facility failures arising from a seismic event include potential criticality, direct radiation hazards, release of radionuclides directly to the environment, asbestos contamination of the environment, and severe economic impact (recovery costs, and opportunity costs associated with the loss of the facility). With respect to the potential criticality accident, the reactivity effects of loss of basin water have been determined and any redistribution of the fuel arrays in the facility necessary to maintain the facility in a sub-critical condition in the event of basin drainage has been completed.

Continued storage of severely deteriorated fuel presents the potential for criticality, radiation exposure, contamination spread, and loss of accountability consequences. Although repackaging and redirection of these fuels to dry storage facilities is a long-term goal, these fuels have been examined, repackaged and relocated to CPP-666 or the south basin for safe interim rack storage. The continued safety of fuel arrays in rack storage is ensured by periodic corrosion inspections.

Part of the residual risk of a criticality accident arising from operation of this facility is the reliance that the ICPP contractor must place on fuel information provided by outside agencies (i.e., the "shipper"). Fuel information is the basis of criticality safety evaluations and the safety analysis to provide handling and storage limits that are critically safe. Although to some extent the fuel information can be checked for internal consistency and verified against

the provider's records, ultimately the ICPP has little control over the quality of this input to the safety analysis. The ICPP contractor also informs the shipper of the use made of the fuel information. This input, fuel information, is the underlying assumption of the ICPP criticality safety program.

The hazard classification for the operation of this underwater fuel storage facility is "moderate" based on the potential for an unplanned criticality, in accordance with DOE-ID Order 5481.1.

2. PROCESS DESCRIPTION

This section describes the process theory and the two main processes associated with CPP-603: (1) the mechanical procedures for fuel receipt (including cask handling), handling and storage and (2) the chemical processes for basin water treatment. In addition, this section includes a process history for the water treatment function.

2.1 PROCESS THEORY

Water is used in the storage basins at CPP-603 primarily to provide shielding to the operators from the highly radioactive fuel assemblies. The water also provides the necessary cooling mechanism for fission product decay heat arising from the fuel elements.

The excellent neutron-moderating properties of water and the large size of the storage basins require special precautions to prevent the accidental formation of critical fuel groupings. Fuel handling and storage equipment must be designed and procedures prepared so that sufficient fuel is not collected in a configuration that can result in a criticality accident. Physical separation between fuel pieces and limits on aggregates of fuel pieces are the primary precautions employed for criticality accident prevention. These concepts are discussed in more detail in Section 5.

Safe and efficient fuel handling operations in any open basin depend upon good visibility through the water. Good visibility, down to the bottom of the basins, is in turn dependent upon maintaining water clarity and quality. Many fuel movements at CPP-603 are operator-aided, requiring the use of hand tools. Consequently, it is essential that visibility through a 20-foot water depth be adequate to allow the operator to grasp, move and manipulate fuel in and out of storage positions, buckets, shipping casks and other equipment.

2.2 FUEL RECEIVING AND HANDLING

Prior to shipment of fuel to the ICPP for storage, sufficient information is required by the ICPP contractor and is provided by the shipper to determine the compatibility of the fuel with ICPP storage and processing facilities. This information is the basis of any necessary safety analysis effort, and criticality calculations. The fuel handling support organization manager or fuel receipt coordinator (as of 1988) provides Fuel Receipt Criteria questionnaire forms to the shipper. Normally, this action is requested by DOE-ID, but the shipper may also request these forms directly. The completed forms are returned to the Fuel Handling organization, either directly or via DOE-ID. The appropriate information may also be provided by the shipper other than by a response to the Fuel Receipt Criteria form, if this requirement is waived by the Fuel Handling management. In any case, the information provided by the shipper includes the following items:

1. Specific reactor name, acronym and core,

2. Fuel type,

3. Fuel composition and geometric shape (fuel alloy, cladding material, fuel form - plates, rods, etc., and void fraction),

4. Fissile material content, fission product inventory, enrichment, burnup data and poison content,

5. Cooling time, decay heat output,

6. Shipping mode, e.g., cask, fuel packaging (cans or baskets),

7. Criticality data, including minimum critical number of pieces, and array k-effective values,

8. Identification of special features, e.g., damaged cladding, special coatings, fuel alterations (from as-built information), irregular shapes, disassembled fuel and attached thermocouples, and the need for special handling tools.

After receipt of this information, the fuel handling support organization determines what reviews, evaluations, approvals and facility/equipment modifications are necessary to prepare for receipt and

storage of a given fuel. The following details are considered in this
determination:

- Processibility of the fuel in an existing ICPP headend
  (i.e., dissolution process),

- Safety of handling and storage in an existing storage facility,
  or necessity to build additional facilities,

- Value of the fuel, and funding necessary for storage and
  disposal/processing activities,

- Other options for fuel disposal, e.g., processing at another site
  or burial,

- Special hazards posed by fuel, e.g., thermal, fission product
  leakage, presence of plutonium, sodium, and

- Shipping package safety documentation (Certificate of Compliance,
  SARP or Transport Plan), and package compatibility with ICPP lift
  equipment.

After these reviews are complete, along with any criticality safety
evaluations and DOE-ID approval of any new safety analysis report,
including addition of the fuel type to the approved fuel listing,
permission may be given to ship the fuel to the ICPP for storage. When
the shipment arrives the shipping papers are examined to verify agreement
with the advance fuel information. The fuel is unloaded and placed into
a designated storage location per relevant procedures and written
instructions. The written instructions, which have been verified to
implement the requirements of the safety analysis report, for an incoming
shipment are provided on a fuel receipt form for CPP-603. Written
instructions are were also provided for fuel transferred to the
FSA (CPP-666) for repackaging and storage, or for transfers between
storage positions at CPP-603.

After each shipment of fuel is unloaded into the storage
position(s), various records are made to ensure accountability during the
fuel storage period and to provide auditable records. A block diagram of
interactions of the fuel handling support organization (i.e., the fuel
receipt coordinator), the field operations and the inventory management
function in accomplishing this activity is shown in Figure 2.

SAFEGUARDS & INVENTORY MGMT.

Preliminary classified data recorded and filed.

Fuel and storage data entered into safeguards computer.

Printouts of inventory generated monthly containing the following data:
fuel type,
receipt date,
qty. of fissile material,
isotopic dist.,
and storage location.

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FUEL HANDLING OPERATIONS

Supervision checks shipping papers for agreement with receipt paperwork instructions provided by support organization for onsite shipments. For off-site shipments, compare Part "C" included with the shipment papers against receipt paperwork provided by support organization

Unloads fuel and stores in accordance with appropriate storage form & instructions.

Supervision completes appropriate paperwork and returns to support organization

FUEL HANDLING SUPPORT

Receives notification of shipment, checks final FRC forms, and gives approval to ship.

Provides appropriate storage form specifying storage location.

Records data from returned information placed on plot plan board and in book.

Files and maintains records of appropriate paperwork, transfers copy to Safeguards and Inventory Management organization.

Either files proper form or transfers to fuel shipping coordinator.

Figure 2. Block Diagram for Fuel Receipt Records

Fuel shipments to the CPP-603 underwater fuel storage facility are received in shipping casks (or chargers in the case of on-site transfers in the ICPP-owned Submarine Thermal Reactor (STR) and High-Load chargers) delivered by truck. A railroad spur also runs through the facility to handle any fuel shipments by rail. Prior to removal from the transport vehicle, the cask is checked for surface contamination and external radiation fields. Any contamination or radiation problems are handled in accordance with the ICPP Radiological Controls Manual.[1] Casks are removed from the transport vehicle with an overhead crane and placed on a decontamination pad near one of the two transfer stations.

Some casks are equipped with temperature indicators that monitor for temperature increases due to decay heat buildup in the cask cavity. If the indicated temperature is in excess of 180°F, measures are taken to cool the cask cavity and fuel to preclude any boiling of the basin water, and subsequent release of volatile fission products when the cask is placed underwater. Cooling of dry and wet shipments is accomplished by air and water purging, respectively. If desired, the coolant in a wet shipment can be sampled to determine fission product leakage from the fuel.

At the north basin transfer station, outriggers (beams designed to engage the support mechanism for the cask lid) are installed on the cask lid, if they are not already provided. The cask is lifted with the overhead crane and lowered into the basin. Fixed vertical rails guide the cask down into the north transfer station, allowing the cask lid outriggers to engage horizontal beams extending between the rails. The beams are located under 14 feet of water in the north basin transfer station. The bolts or other devices securing the lid to the cask body must be removed before the cask is put in the water to allow these beams to engage the lid and hold it as the cask is lowered further. Once the cask lid is fully disengaged, the cask is moved laterally under water from beneath the supported cask lid.

The fuel can be removed from the cask cavity with one of several types of hand tools (depending upon the type of fuel being unloaded). The tool is manipulated by an operator at the transfer station. At the north basin transfer station, fuel is supported by a hook device and placed on a monorail or loaded into one of three basic types of hanging buckets also on the monorail. The hanging fuel is then moved by hand via the monorail to its storage location in either the north or the middle storage basins. After each shipment of fuel is unloaded into its storage location, various records are made to ensure accountability during the storage interval and to provide a record for audit and to record compliance with storage limits as discussed previously.

For the north transfer station, the unloaded cask is then returned, laterally, to a position directly beneath the lid and against the vertical guide rails. It is raised through the water, reengaging its lid. From the time the cask top emerges from the basin surface, water from a ring of spray nozzles and a small hose continually washes the cask down to remove any contamination from the cask as it is lifted from the basin water. The cask is suspended over the transfer station until virtually all water drains from the cask cavity. It is then returned to the loading platform and wiped dry. The cask is surveyed for surface contamination, decontamination is performed as necessary, and the lid and locking mechanism are bolted down. Onsite casks are wrapped in plastic film, if necessary, to contain any residual surface contamination. Offsite casks are decontaminated more extensively and are not wrapped in plastic. The cask is then tagged "Empty" and placed on and secured to the transport vehicle for return to the shipper.

The procedure for handling of casks at the south basin transfer station is slightly different. In this case, for casks containing fuel in excess of a minimum critical number of pieces, sufficient closure devices are left in place on the cask lid to ensure that the lid will remain on the cask in the event of a drop accident. The cask is lifted with the overhead crane and placed on the south basin transfer station floor. The cask closure devices (if present) and the cask lid are removed from the cask to provide access to the fuel. Removal of the fuel from the cask and transfer to south basin storage are very similar to the procedure at the north basin transfer station.

The south basin transfer station is served by a fuel handling bridge crane, aka the catwalk crane. During fuel unloading operations the bridge serves as a walkway for the operator to move fuel by hand from the transfer station to its fuel storage rack position. If the weight of the fuel pieces is so great that transfer by hand is not possible, a special hoist is used for lifting and carrying the fuel with the bridge crane.

The removal of fuel from storage for processing or for transfer to the FAST underwater fuel storage facility follows nearly the same procedure, but in reverse, and is accomplished using the ICPP-owned High Load and STR charging casks. First, the storage location of the fuel to be processed is determined from the basin plot plan and from the batching schedule. The empty charging cask (i.e., "charger") is then lowered into the appropriate transfer station. The fuel is removed from a storage location and loaded, one fuel handling unit at a time, into the charging cask.

When loaded, the lid is placed on the charger, secured, and the charger is raised and sprayed as before, decontaminated as necessary, and tagged as "Loaded." Both chargers are used for the transfer of fuel handling units to the process. To transfer multiple fuel handling units, a poisoned 3 x 3 insert is used in the High Load Charger as specified for given fuel types. The chargers and operating limits associated with their use are discussed in PSD Section 4.5. Before transfer of fuels from the CPP-603 basin, fuel handling supervision completes the appropriate inventory and accountability forms.

2.2.1 Fuel Receiving and Handling - Specific

The procedures for receiving and handling specific fuels at CPP-603 may vary somewhat from the general procedures just described, according to the design of the transport cask, the specific storage location, or the method of storage. The following sections describe the specific procedures for the three principal general fuel types received and stored at CPP-603: stainless steel clad, aluminum clad, and zirconium clad. These procedures also apply to the miscellaneous fuels depending on the storage mode.

2.2.1.1 <u>Stainless-Steel-Clad Fuels</u>. The bulk of the stainless-steel-clad fuel received at the ICPP originates from the ANL-W Experimental Breeder Reactor II (EBR-II). EBR-II fuel is unloaded at the CPP-603 facility in the south basin transfer station. The HFEF-6 cask cavity is filled with a coolant. Water is generally used for this purpose except when freezing weather conditions require the use of antifreeze solution. Selection of the antifreeze (e.g., $NaNO_3$) is mutually agreed upon between ANL-W and the ICPP. If the shipping papers show that an antifreeze is being used, the coolant is flushed from the cask cavity to the hot waste tank (VES-SFE-126). The HFEF-6 cask is equipped with a drain connection at the bottom and a vent (overflow) near the top. When antifreeze is present, temporary hoses and valves are attached to allow water to be back-flushed through the cask from bottom to top. After the effluent is drained to the hot waste tank (VES-SFE-126), the attached equipment is removed.

The water-filled cask is moved to the south basin transfer station. Here the cask cover plate is removed, and the cask raised from the loading platform into the transfer station. The cask is rinsed with water as it is lowered into the transfer station where the fuel containers are removed from the cask with a fuel handling tool after the shield plug lid has been removed. The fuel is carried under water to the stainless steel fuel storage racks (RK-SF-900) in the south storage basin. Up to sixteen EBR-II fuel containers may be stored in each rack position, stacked in two tiers of eight containers each. A rack pedestal physically separates the two tiers and prevents fuel in the upper tier from slipping into the lower tier.

EBR-II fuel containers may be removed from four-container "carriers" and placed in a "rack insert" designed to hold eight containers. This configuration enables more efficient handling and enables more efficient storage at CPP-666, Fuel Storage Area (FSA), when this fuel is transferred from CPP-603. This operation would be performed either when the fuel is received from ANL-W or as the carriers are removed from RK-SF-900 racks at CPP-603 and prepared for transfer to the FSA. Reconfiguring of the fuel handling units (FHU) from carriers to rack inserts is conducted in the south basin transfer station with the use of

a "carrier stand" and a rack insert stand," which assure isolation from other fuels for the prevention of criticality. After the rack insert is loaded and removed from the insert stand, it is transferred as a FHU either into storage in a RK-SF-900 rack for transfer at a later date or into the STR charger for transfer to the FSA. Details of the fuel reconfiguring operation, as well as the safety analysis, are covered in PSD Section 5.6, Volume III, Addendum B.

2.2.1.2 Aluminum-Clad Fuels. The most common aluminum-clad fuels received at ICPP are from test reactors. These fuels are shipped to the ICPP from domestic and foreign reactors. Common domestic sources of aluminum-clad fuel are university reactors. The Idaho National Engineering and Environmental Laboratory (INEEL) Advanced Test Reactor (ATR) is one of the largest sources of aluminum fuel in ICPP storage. These fuels consist only of the fueled section; the inert end boxes are removed at the reactor before shipment to the ICPP. Aluminum-clad fuels are unloaded in the south transfer station and are stored in the aluminum racks in the south basin per the general procedure outlined above. Aluminum fuels are also approved for bucket storage on the monorail system in the north and middle basins. In that case, casks are unloaded in the north basin transfer station.

2.2.1.3 Zirconium-Clad Fuels. The zirconium-clad fuels received at ICPP come principally from the Naval Reactors Facility (NRF), specifically the Expended Core Facility (ECF), located on the INEEL site. They are shipped to the ICPP in the ICPP-owned chargers, the High Load or the STR. These fuels are also shipped to the ICPP in the NFS-100 cask, owned by NRF. These fuels are unloaded at ICPP in the north and south transfer stations and stored in the north, middle, and south storage basins. The NFS-100 cask is operationally compatible only with the south basin transfer station. The zirconium-clad fuels are stored in stainless steel racks (RK-SF-900) in the south basin.

For fuel storage in the north or middle basins, casks are placed in a pit of the north station as described previously. A hanger (yoke) is then moved on the monorail to the hydraulic lift section of the monorail above the lowered cask. A hanging fixture is used to attach the fuel to the yoke unit. Once the fuel is attached to the yoke, the hydraulic unit

lifts the fuel out of the cask as far as it will extend. Generally, the cask must then be lowered to fully remove the fuel. The yoke is then moved to a storage position in either the north or the middle basin. The emptied cask is removed from the basin by reversing this procedure.

The fuel is stored on the hanging yokes in north-south rows in both the north and the middle storage basins. Thirty-in.-high concrete dividers, 12 in. thick, define the rows. Bumpers on the yokes at the top of the hanger ensure 18-in. spacing between yokes. Bumpers under water near the bottom of the hanger also assist in the spacing (see Section 3.0 for further description of this equipment). No fuel is permitted to be stored permanently in any east-west portion of the monorail nor on the turntable. However, these east-west transfer regions may temporarily hold a number of hangers while fuels are being moved or inventoried.

Fuel to be processed or transferred to the FAST Fuel Storage Area (FSA) at CPP-666 is removed from storage by following the unloading procedures in reverse.

2.3 WATER TREATMENT

Two of the major operational considerations at CPP-603 are the presence of fission products in the basin water and undissolved solids that settle as sludge on the basin floor. The presence of fission products in the basin water (approximately 4×10^{-5} microCi/mL) does not limit basin operations. Dissolved radioisotopes are removed by ion-exchange systems. The concentration of various chemical species and radionuclides in the basin water for different times in the past is reported in Table I. The chloride ion and radionuclide levels have continued to decrease.

Undissolved solids exist in the basin water as suspended particulates and are continually settling on horizontal surfaces of the basin to form sludge. These particles are composed of desert sand and dust, precipitated corrosion products, and metal particles from past cutting operations. The contribution from precipitated chemicals used to scavenge fission products, dead microorganisms, and material eroded from

Table I. Chemical and Radionuclide Composition of CPP-603 Water

Chemical Constituent	Concentration, ppm		
	9/76[2]	1/81[2]	8/88[3]
Calcium (Ca^{+2})	20	22	1.5
Magnesium (Mg^{+2})	2.5	1.6	<0.01
Iron (Fe^{+3})		.03	<0.009
Sodium (Na^+)	710	516	120
Chloride (Cl^-)	715	284	58
Nitrate (NO_3^-)	590	682	217
Sulfate (SO_4^{-2})	55	36	*
Phosphate (PO_4^{-3})	<.05	<.02	*
Bicarbonate (HCO_3^-)	58	121	*
Silicon (Si^{+4})	3.5	9	9

Radionuclide	Concentration, microCi/mL		
	9/76[2]	1/81[2]	8/88[4]
Cs-137	0.035	2.06×10^{-4}	2.89×10^{-6}
Cs-134	0.0018	0.03×10^{-4}	0.01×10^{-6}
Sr-90	0.015	0.52×10^{-4}	0.28×10^{-6}
Sr-89	0.04	0.03×10^{-4}	not detected
Co-60	0.0004	0.08×10^{-4}	0.01×10^{-6}
Y-90	0.015	0.52×10^{-4}	0.28×10^{-6}
Sb-125		1.59×10^{-4}	0.04×10^{-6}
Totals[b]	0.12	4.9×10^{-4}	3.52×10^{-6}

* Not analyzed.

[b] Not all contributing radionuclides listed; totals are accurate for each column.

the concrete basin walls is no longer significant. When disturbed by turbulence, the sludge can pose a serious problem to visibility.

The physical and chemical properties of the basin water must be controlled to (1) minimize fuel element corrosion (of fuel cladding), which in turn will reduce the amount of radioactivity that may be leached from exposed fuel meat to the water and will maintain control over fuel configuration for criticality safety; (2) ensure clarity for proper visibility; and (3) remove radioisotopes from the water. These are accomplished by filtration and ion exchange of basin water, and, previously, has been accomplished by the mechanical removal (e.g., vacuuming) of sludge deposits from the basin floor. Chemical additions to the basin water are administratively controlled.

The basins and canal at CPP-603 contain about 1.5 million gallons of water. Makeup water to replace that lost by evaporation and by transfers to liquid waste is provided from the rinsing of fuel casks, or is added directly to the basin from the reverse osmosis demineralization unit. Basin water is clarified by continuously circulating a stream under pressure through a mixed media (sand) filter system, which consists of filtration through anthracite and garnet sand to remove suspended dirt, microorganisms, and crud. Additional purification is provided by an ion-exchange system for removal of strontium, cesium and other cations, which is fed by the discharge from the sand filter system. In addition to these capabilities, there is also a chloride removal system and an ultraviolet light sterilization system.

The function of the various basin water treatment systems and a process history are discussed in the following subsections.

2.3.1 History of Basin Water Quality Improvements

Many of the engineering problems associated with the CPP-603 underwater storage facility involve processes for treating and maintaining the water quality in the three interconnected basins. Over the more 30-year span of operation, substantial amounts of contaminants have been released into the basin water. These contaminants include radionuclides from the fuel, chemicals naturally occurring in raw water

and those chemicals intentionally introduced for corrosion inhibition and bacteriological control. Additional problems also have occurred as sand and dust seeped through cracks in the building's superstructure and eventually settled in the basin along with corrosion products, precipitated chemicals, and dead microorganisms.

Prior to 1963, the facility was operated with a continuous raw water purge, with the excess water flowing to an open-bottom manhole and percolating down through the soil. The radionuclides were removed from the water by an ion-exchange reaction with the soil. Beginning in late 1963, the excess water was processed through an ion exchange system before release to the manhole. This ion-exchange system consisted of eight drums of clinoptilolite, a naturally occurring zeolite. The combination of ion exchange and purging removed the radionuclides (without release) and maintained the concentration of other chemicals in the water at a constant value.

In late 1966, the continuous purge operating mode was discontinued, and the system became a closed loop with respect to circulation of basin water. The radionuclides were still being removed by the clinoptilolite ion-exchange system, but the other chemicals were accumulating. Due to the increased growth of microorganisms in the water, increased treatments were necessary for control and the concentrations of chloride ion, nitrate ion, calcium, magnesium and sodium increased steadily.[2] In 1973, the ion-exchange process by use of the drums was replaced by what is now referred to in this document as the "old ion-exchange system."

The concentration of chloride ions gradually increased to a maximum of about 750 ppm in 1975 as chlorine gas and calcium hypochlorite were added to control the growth of microorganisms. Although the hypochlorite ion is effective in destroying microorganisms, the resulting chloride level allowed unacceptable corrosion of aluminum. Direct chlorine gas additions were replaced by using iodine, along with adding small quantities of calcium hypochlorite to oxidize the I^- to the I_2 elemental form. Calcium hypochlorite was used since it could be easily spread throughout the basin, whereas the chlorine gas could be injected at only

one point. Sodium nitrate was also added to minimize corrosion of Al by Cl⁻.

Other methods of controlling the growth of algae and bacteria (microorganisms) were evaluated and tested. These methods included (1) ozone additions, (2) hydrogen peroxide and iodine additions, and (3) sterilization with ultraviolet (UV) light. The use of UV light, which was started in 1978, was found to be more practical than either ozone or hydrogen peroxide additions.

The effectiveness of UV light for sterilizing purposes was tested by flowing water through an array of 12 UV lamps enclosed in quartz sleeves. The UV light killed greater than 99% of the microorganisms in both well water and basin water. The main disadvantage of using UV light to sterilize water is its lack of residual killing power. The rapid turnover of water through the mixed media filter system and UV lamps, however, permits control of the microorganisms by such radiation. The UV method of water sterilization is routinely used at the CPP-603 facility. As backup, iodine, with hydrogen peroxide as the oxidant to oxidize iodide to iodine, is available.

The systematic use of iodine and calcium hypochlorite had several advantages over chlorine when used as a bactericide, including less corrosion of metals, a lower addition rate, and less dependence on pH adjustment. The principal disadvantage was that iodine does not kill algae and thus would have required that an algaecide also be used. Iodine was injected into the basin on an experimental basis, but an algaecide was used only one time.[3]

In CY-76, the chloride removal system was installed to decrease the basin water chloride concentration by reverse osmosis through a semipermeable membrane. The eventual goal for this unit was to reduce the chloride concentration to <50 ppm. Operation of the chloride removal system was discontinued after several years since it was no longer effective, and there was significant radiation exposure associated with operating the system. The 50 ppm Cl⁻ goal was not reached, but by the 1980's the concentration stabilized between 60 and 70 ppm. Continued

reductions of the concentration below the current (1988) level of 58 ppm will be from dilution of the basin water from external water sources.

By the mid 1970's, the radionuclide concentration of the basin water had reached very high levels. The source of the contamination was determined to be stored EBR-II fuel assemblies. The contribution of this fuel to the contamination problem was eliminated when the fuel was disassembled and canned prior to shipment to the ICPP. The ion-exchange system was effective in the removal of radionuclides from the water.

Control of basin water purity was greatly improved by adding the multimedia filter system in 1976. Larger, more efficient ion exchangers were added in 1980 (i.e., the "new ion-exchange system") to receive the effluent stream from the filter system and remove fission products from the basin water. A new reverse osmosis unit for demineralization of the raw water supply was installed on the incoming water line. This unit improves the overall efficiency of the ion-exchange system.

In 1978, the fuel storage basin underwent an extensive cleanup project to remove a 5- to 10-cm layer of sludge from the basin floor and a lesser amount from the walls. This operation was performed by an outside contractor. Although a thin coat of sediment remains on the basin floor, the operation successfully eliminated most of the problems associated with poor visibility when the sludge was disturbed.[5]

An underwater vacuum system was used to pick up the sludge. The debris was transported through a flexible line to a hydroclone where it was separated into (1) a concentrated sludge, which was placed in temporary storage in a large stainless steel tank; and (2) water containing finely divided solids, which was returned to the inlet of the sand filter system. The sludge was then pumped from the sludge storage tank into concrete steel-lined vaults, where it was solidified and finally placed in storage at the Radioactive Waste Management Complex (RWMC).

2.3.2 Water Treatment Functions

The functions of the water treatment system are described below.

2.3.2.1. **Filtration**. A pressurized filter system (1000-gpm capacity) using mixed media (anthracite and garnet) was installed in the CPP-603 area at the east end of the south basin. This system uses three pressure filter tanks (F-SF-113/114/115), a backwash solution hold tank (VES-SF-108), a clarifier tank (VES-SF-109), two recirculation pumps (SF-P-214/215), and two transfer pumps (SF-P-216/217). This system pumps water at a maximum of 1000 gpm from the east side of the south basin and discharges the filtered water to the west side of the south basin. Water from the system is also pumped to the north and middle basins for recirculation.

Under normal operating conditions, backwash of the filters is initiated manually, when needed. The backwash water and filtered solids are then pumped by the transfer pumps (SF-P-216/217) from the hold tank (VES-SF-108) to the conical-shaped clarifier tank (VES-SF-109) where solids settle and the supernatant water is decanted back to the basin. The accumulated solids in the clarifier are transferred to the sludge storage tank (VES-SFE-106) intermittently.

2.3.2.2. **Ion-Exchange**. The ion-exchange systems were designed to remove radionuclides (principally strontium and cesium) from the basin water to reduce the direct radiation levels above the basin water and to reduce contamination of casks and equipment. As of August 1980, dual ion-exchange systems were in operation at CPP-603. Both systems have the same components; however, the most recently installed system (i.e., the "new ion-exchange system") is physically larger than the original with a capacity of 150 gpm. The old ion-exchange system capacity is 60 gpm. The combined systems process a volume of water equivalent to the total volume of the basins five or six times each month.

A portion of the basin water discharging from the filter system is diverted to the two ion-exchange columns (VES-SF-101/102) of the old system in series and then discharged to the middle fuel storage basin and the fuel transfer pits in the north transfer station. VES-SF-101 and

VES-SF-102 were both charged with Zeolon 900 for cesium removal. As of 1988, VES-SF-102 did not contain any resin (was in standby status), and VES-SF-101 was filled with PDZ-14010, a naturally-occurring chemically-treated clinoptilolite. The PDZ-14010 material is being tested to determine its efficacy for cesium removal. This product is being considered as a replacement material for Zeolon 900, which is no longer available. The Zeolon 900 inventory on hand is sufficient for approximately 18 months of operation.

The new ion-exchange system, VES-SF-131 and -132, is also fed by the filter system discharge or an alternate feed configuration can be used. The VES-SF-131 column contains Duolite 464 resin for strontium removal, while the -132 column contains Zeolon 900. The Zeolon 900 is not regenerated but is replaced about every 6-12 months, when cesium breakthrough reaches 50%. Spent resin is pumped as a slurry in water supplied by pump P-SF-201 or P-SF-202 to the sludge storage tank (VES-SFE-106). New Zeolon is added to the columns as a water slurry from a resin hopper (HO-SF-800).

The Duolite 464 resin in VES-SF-131 is periodically regenerated with 3% HNO_3 solution. This solution is prepared in regenerant acid tank VES-SF-130 by adding 13 $\underline{M}$ HNO_3 to water supplied from the reverse osmosis demineralization unit. The regenerant solution is pumped out of VES-SF-130 with pump P-SF-230 for addition to VES-SF-131. The used regenerant and rinse solutions are drained to the hot waste tank (VES-SFE-106) and the supernate is ultimately disposed of to the CPP-604 PEW evaporator system.

2.3.2.3. <u>Chloride Removal System</u>. The chloride removal system has not been operated for several years. However, when it was in operation, water was fed to the system's reverse osmosis (RO) unit, VES-SF-121, from VES-SF-102 ion-exchange column or directly from the basin water. Prior to being fed to the RO unit, the water was filtered to remove undissolved solids, the pH was adjusted (with nitric acid) and commercial bleach (sodium hypochlorite) was added to kill bacteria. The RO unit produced a low-chloride permeate stream and a high-chloride concentrate stream. The permeate, containing 10% of the Cl⁻ in the feed, was returned to the

basin. The concentrate stream, which also contained dead bacteria, was processed by the evaporator, VES-SF-123, to convert the liquid into a solid sludge containing mostly NaCl and NaNO$_3$ salts.

2.3.2.4. Reverse-Osmosis Demineralization. The purpose of the reverse osmosis demineralization process is to reduce the dissolved solids content of the raw water fed to the facility. A combined nitric acid and raw water stream is fed to the system. Prior to introduction to the system, the water can be fed to a multimedia filter (F-SF-134) and an ultraviolet purification unit, STER-SF-103. The demineralized water is routed to the middle basin, VES-SF-130, VES-SF-103 or VES-SF-104.

2.3.2.5. Ultraviolet Light Sterilization. The ultraviolet light system was installed above the transfer canal near the south basin to kill bacteria in the water.

2.3.2.6. Sampling. Periodic samples of the CPP-603 fuel storage basin water are taken and analyzed for pH, nitrate, chloride, and other compositions of interest.

3. PROCESS DESIGN AND EQUIPMENT

The facilities and equipment for underwater fuel handling and basin water treatment are described in this section.

3.1 FACILITY DESCRIPTION

The underwater fuel storage facility and related equipment for fuel handling and water treatment are housed in the CPP-603 building, except for the sludge storage tank (VES-SFE-106), which is contained in an underground vault east of CPP-648. In addition to these buildings, the hot waste tank (VES-SFE-126) is housed in an underground vault, CPP-764, southeast of CPP-642 which is the pump pit for CPP-603 hot waste. The CPP-603 air compressor is also in CPP-642. A personnel area, CPP-626, is attached to CPP-603 at the northwest corner. The layout of CPP-603 and the associated buildings is shown in Figure 3.

The CPP-603 building is located approximately 0.5 mile south of the process building, CPP-601, inside the ICPP perimeter fence. The building is connected to the other ICPP areas by an asphalt-surfaced road. An asphalt-surfaced road circles the building, and rejoins the main roadway north of the building. A railroad spur runs east-west through the building adjacent to the south wall. The surface and belowgrade portion of CPP-603 are constructed of reinforced concrete. The superstructure is constructed of structural carbon steel with corrugated asbestos siding (i.e., transite) on the outside walls and roof, and flat asbestos siding on the inside, with fiberglass insulation between the siding layers.

The Irradiated (Dry) Fuels Storage Facility (IFSF, see PSD Section 4.12) is an extension of the CPP-603 building to the west, attached at the southwest corner of the main building structure. The IFSF is located so that it can be served by the 75-ton crane and the railroad spur.

As shown in Figure 3, the facility includes a personnel area in CPP-626, which houses personnel offices, a change room and a lunchroom.
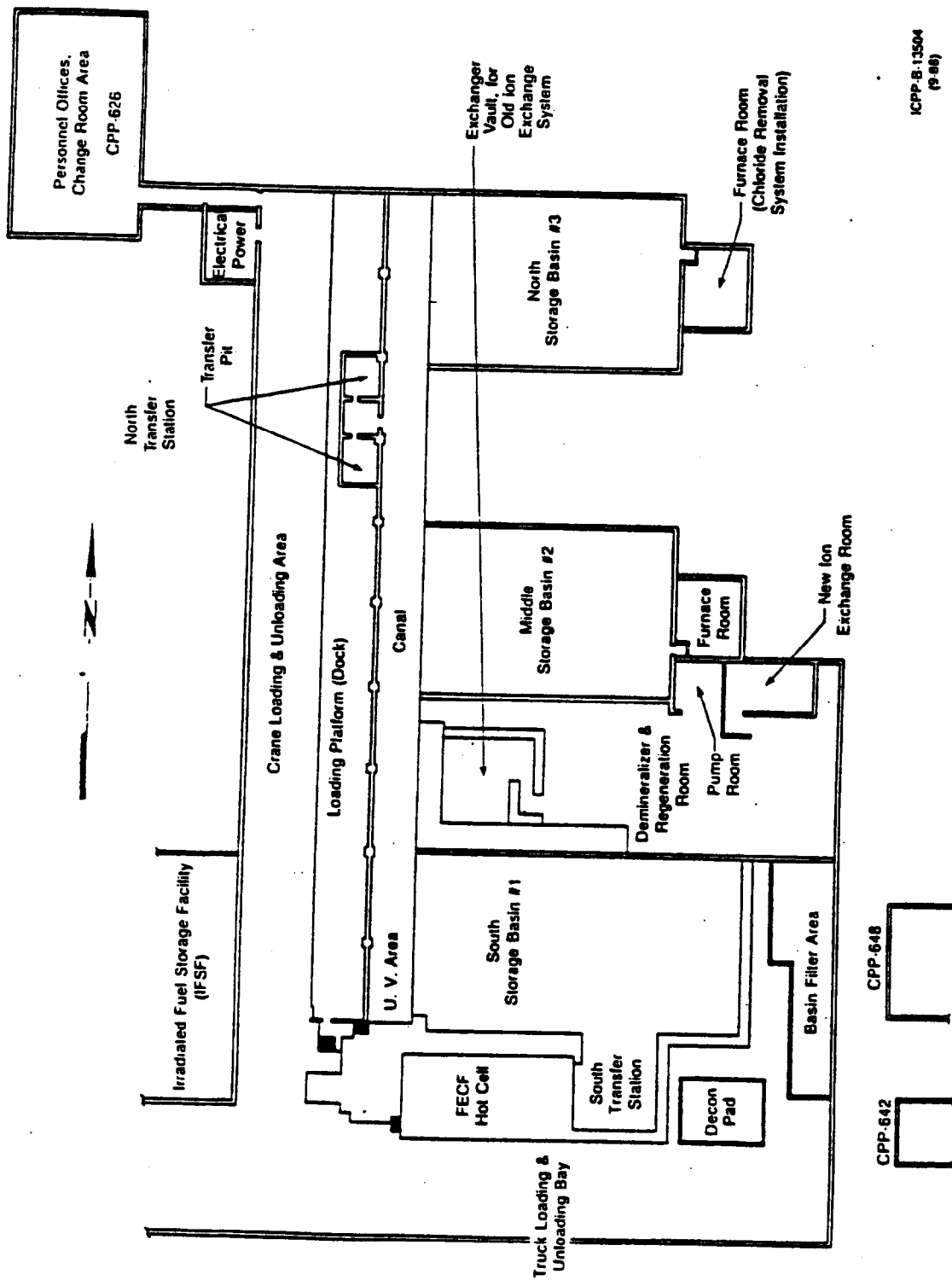
Figure 3. CPP-603 Fuel Storage Facility Layout

Note: CPP-764 (location of VES-SFE-126) underground and S-E of CPP-642.

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Adjacent to, and south of, the CPP-626 connecting hallway (to the west crane bay) is an electrical power distribution room. The CPP-603 facility includes three basins connected by a canal at the west end that parallels the west crane bay and is perpendicular to the Fuel Element Cutting Facility (FECF). Small rooms are attached to the east end of the north and middle basins and were originally designated as furnace rooms. They contained heating equipment, water recirculation pumps and filter equipment. The room attached to the north basin has housed the equipment for the chloride removal system since 1976, and the room attached to the middle basin is not currently being used.

3.1.1 Crane Bays

The west crane bay portion of the CPP-603 building is 200 x 29 x 36 feet high with a gabled roof and a 16-foot wide concrete driveway extending the length of the facility with rollup metal doors at each end. East of the roadway and 3-feet 9-in. above it is a 12-1/2-foot-wide concrete platform extending the length of the bay. This crane bay is serviced by a 15-ton capacity crane with a 27-foot span that extends the length of the bay. Maximum lift for the crane hook is 20 feet above the concrete driveway.

The south crane bay is 137 x 20 x 40 feet high with a gabled roof and 14-foot wide concrete driveway (which includes the railroad spur tracks) extending the length of the area with rollup metal doors at each end. This portion of the building contains a decontamination pad, the south transfer station and the FECF. The south crane bay is serviced by a 15- or 75-ton crane with a track span of 37 feet that extends the length of the bay. The maximum lift height for the crane hook above the railroad track is about 25 feet and from the concrete pad is about 27.5 feet.

3.1.2 Transfer Canal

The transfer canal, 8 feet wide and 21 feet deep, is located adjacent to the west crane bay and connects the three storage basins. The canal area is separated from the crane bay by a transite wall. The canal is covered by a floor grating overlaid with lead-plate shielding

(aluminum clad). The grating is supported on concrete beams mounted on the canal walls and on concrete piers set in the floor. At the south end of the canal is a 7 x 10 foot pit, isolated from the rest of the canal by a concrete wall and covered by steel deck plate. This pit is the original overflow and pumping area for the early water treatment systems. There are three inlets to the pit from the basin water, at the surface, at the bottom and below the center grating support. At the present time the UV lights are located in this area.

A monorail track extends overhead on both sides of the canal. A turntable and crossover track are located at the entrances to the north and middle storage basins and the north transfer station. There are 1.5-in.-wide continuous slots in the canal grating under the tracks.

3.1.3 Storage Basins

The north and middle basins are 40 by 60 feet and 21 feet deep, and are covered with fiberglass floor grating. Aluminum-clad lead plate is installed over the grating for radiation shielding (primarily from activity associated with scum accumulation at the water line). The two basins are divided into channels by concrete beam spacers supported on piers. The spacers are 2 feet high and 1 foot wide on 2-foot centers. Fuel is suspended from the monorails in these channels. The south basin is an open pool 45 by 88 feet and 21 feet deep.

3.1.4 Fuel Element Cutting Facility

The Fuel Element Cutting Facility (FECF) is a shielded hot cell adjacent to the south storage basin. The space is used only for dry storage of two Peach Bottom fuel elements. The Fort Belvoir rack, formerly used for the storage of EBR-I Mark IV fuel, is still located in the FECF. The cell cavity is L-shaped, measuring 19 feet long, 6 feet wide at the narrow end, 9 feet wide at the wide end, and 14-1/2 feet high. Three feet of concrete shielding are provided on the east, south, and west walls and the ceiling and two feet on the north wall (basin side). A 20-ft tunnel extends from beneath the cell westward to a cask handling pit. The cask handling pit is an area 5 ft square in the floor of the CPP-603 area (adjacent to the FECF) into

which fuel casks were formerly lowered. A roof hatch exists for access to the cell cavity. The FECF is open to the south basin via an underwater slot in the FECF. Four viewing windows exist in the south and west walls of the FECF.

3.1.5 Decontamination Areas

Adjacent to both sides of the north transfer station are concrete areas with hose connections and floor drains, designated for cask cleanup. Contaminated casks and equipment must be handled in the south decontamination area, located immediately east of the south transfer station. This area, 16 by 20 feet, is lined with stainless steel and surrounded by a concrete curb, 6 in. in height. This area drains to the hot waste tank VES-SFE-126, and solutions are pumped to the CPP-604 PEW system for further treatment.

3.2 FUEL HANDLING EQUIPMENT

Fuel handling equipment discussed in this section includes the transfer stations and the fuel handling tools.

3.2.1 Transfer Stations

At CPP-603, fuel is received and loaded through two transfer stations. The south transfer station, an area 20 ft wide, 25 ft long, and 21 ft deep, is located on the south side of the south storage basin, immediately east of the FECF. The north basin transfer station, an area 6-1/2 feet wide and 25 feet long, is located on the west side of CPP-603 midway between the north and middle basins. The transfer station locations are illustrated in Figure 3.

The north basin transfer station consists of two nearly identical cask loading/unloading pits with a fuel handling area between, as depicted in Figure 4. Of the two pits, north and south, only the north transfer pit is used. Simultaneous loading/unloading of casks in both the north pit and the spare south pit is impossible because only one crane services the area.
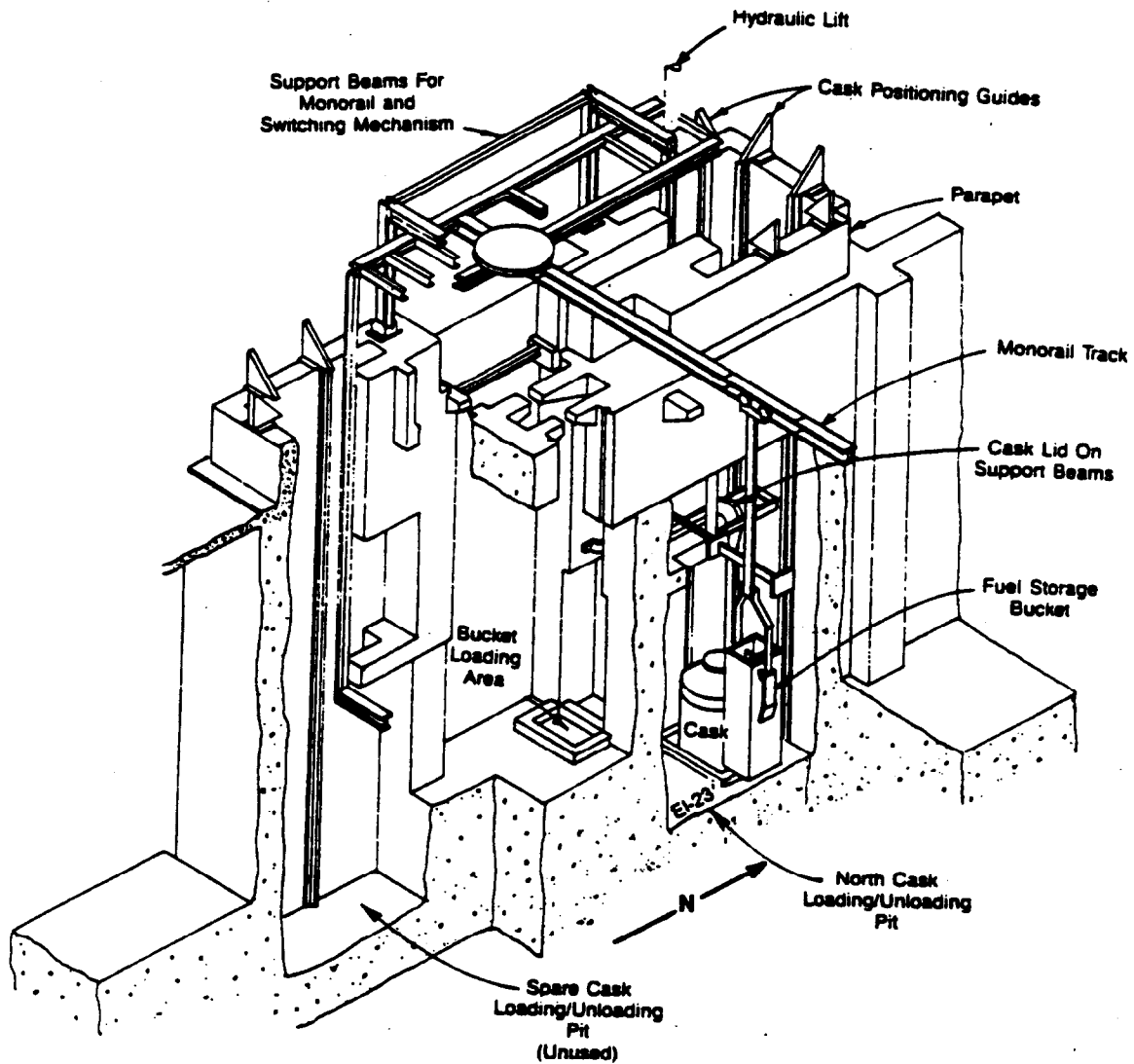
Figure 4.   North Transfer Station

The north cask pit is about 6 ft 4 in. wide, 8 ft 10 in. long (north-south), and 26 feet deep. The fuel handling area is 6 ft 4 in. wide, 4 ft 1 in. long, but only 21 feet deep. Six I-beam guides are positioned on the west, north, and east parapet walls of the north pit to assist in aligning the casks before they are lowered into the pit. Steel I-beam rails are installed integrally with the guides on these same three pit walls to guide the casks into the pit. Horizontal steel rails, located approximately 14 feet below the top of the water, engage outriggers on the cask lid and hold the lid while the cask is lowered to near the bottom of the pit. This sequence is shown in Figure 5.

A 1000-lb-capacity hydraulic lift is located at each pit to remove fuel from the casks. The lift is connected to an end section of the monorail system. When removing fuel from a cask, the lift lowers the entire monorail section, with the yoke in place, until the hook on the yoke engages the bail or eye of the fuel piece. The lift then raises the monorail section until it engages the fixed monorail.

The south basin transfer station is much simpler in design than the north transfer station. Cask positioning guides and a cask lid support framework were used in the past, but have been removed to accommodate larger casks in the south transfer station. The south basin transfer station is simply an open pool attached to the south basin.

3.2.2 Fuel Handling Tools

Several types of special handling tools exist for grasping and transporting fuel within the basin. Generally fuel handling tools are more important at the south basin, since they are used to remove the fuel from and to transfer the fuel to the storage racks. At the north basin transfer station, tools are used to transfer fuel to a bucket.

Lid

Outriggers

Support
Beam

Cask

Sequence A
Lowering Cask - Lid Suspended

Sequence B
Cask Moved Laterally

Sequence C
Fuel Unit Being Removed From Cask

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(8-88)
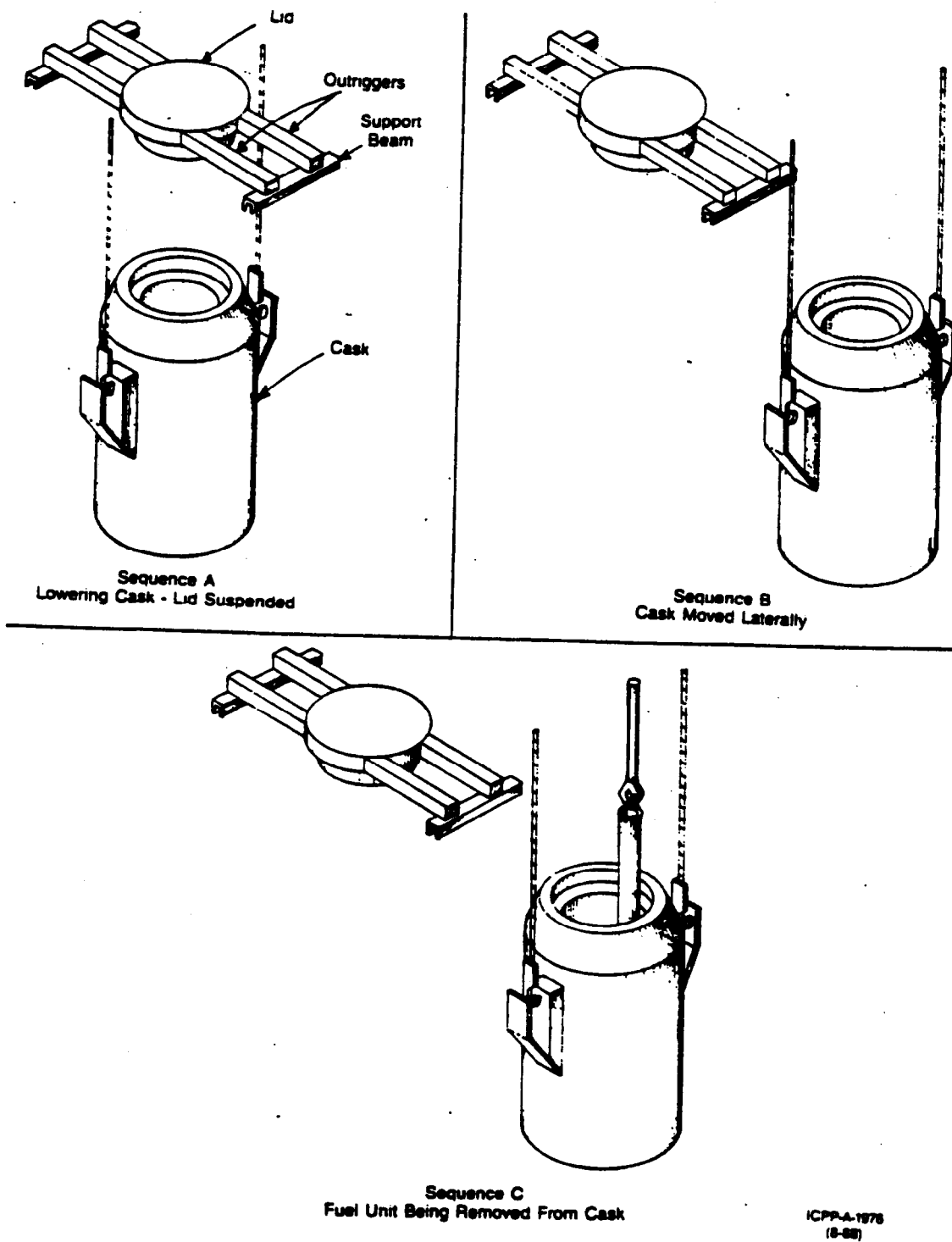
Figure 5.   Cask Handling at the North Transfer Station

Frequently, new tools are designed and built specifically to handle a new fuel. Most have simple lifting hooks, as shown in Figure 6. Others have more complicated mechanical devices, such as locking jaws with tightening gears, operated by small wheels.

Fuel handling tools are designed to enable the operator to manipulate the fuel from the side of the basin (or above it from the 1-1/2-ton bridge crane) and still maintain the fuel at a safe water depth for shielding.

3.3 CASK HANDLING EQUIPMENT

Cask handling equipment consists of the CPP-603 cranes and auxiliary lifting devices. In addition to those types of items, various types of hand tools (wrenches, etc.) are used to loosen bolts to separate the cask from a pallet or skid, remove an outer cover or jacket and to remove the cask lid.

3.3.1 Cranes

Three bridge cranes serve the CPP-603 underwater area. CRN-SF-301 is the 15-ton crane in the west crane bay, CRN-SF-35 and CRN-SF-001 are the 15-ton and 75-ton cranes, respectively, in the south crane bay. The 75-ton crane is rated only at a 60-ton capacity since 60 tons is the largest weight available for load testing. These cranes are used to remove casks/chargers from the vehicle and transfer them into the transfer stations. Casks in excess of 15 tons must be handled at the south basin with the larger capacity crane. In addition to these cranes, there is also the mobile 1-1/2-ton catwalk crane (CRN-SF-002) over the south basin, which is used to assist in fuel transfer operations and to move racks from the south basin. The catwalk crane is also used to transfer fuel from the south basin transfer station to the south storage basin.

Top Hook
Stainless Steel

Handle
Aluminum

~ 21'

Lifting Hook
Stainless Steel
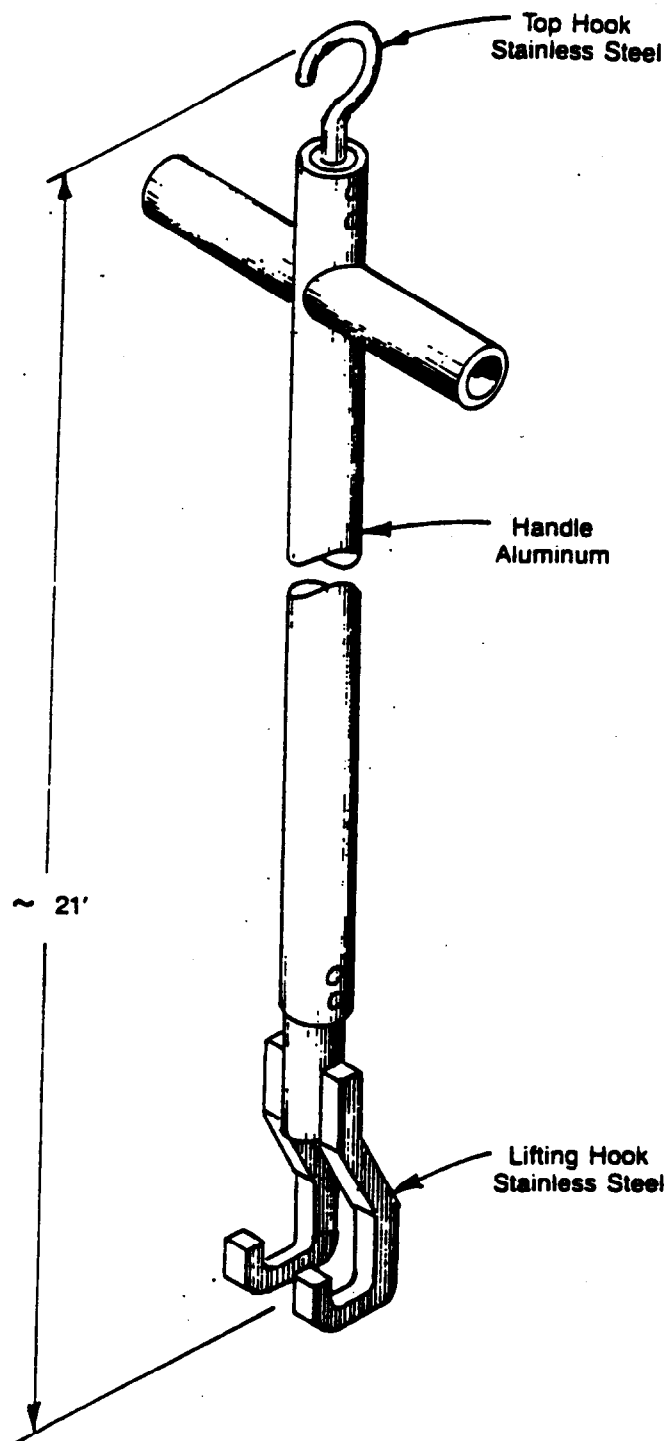
ICPP-A-2111
(11-86)

Figure 6.   Fuel Handling Tool with Lifting Hooks

3.3.2 Auxiliary Lifting Devices

The cranes are used to lift casks/chargers with various types of auxiliary equipment. These items includes slings, safety harnesses, truck and basin load bars (long or short) and lid lifting devices. The selection of equipment for cask handling is determined by the cask design features, the weight and the overall dimensions. Various combinations of load bars and slings or chains are used, depending on the method for removal of the lid from the cask body. In addition, lifting yokes (i.e., load bars) are often supplied by the shipper of the cask for use at the ICPP. An example of a load bar is shown in Figure 7.

3.4 FUEL STORAGE EQUIPMENT

The fuel storage equipment consists of the monorail system (buckets and hangers) and the racks in the basins and in the FECF.

3.4.1 Monorail System

The monorail system services both the north and middle fuel storage basins and the interconnecting transfer canal. The system is a Louden Monotrack with T-rail 2-7/16 in. deep and 2 in. wide. The web is 7/32 in. thick, and the bottom flange is 11/32 in. thick. The rails are carbon steel and are supported by the 10-in. roof I-beams of the CPP-603 superstructure. Turntables exist in the monorail system in the canal just east of the north transfer station, just west of the entrances of all three storage basins, and at the south end of the canal.

There are also turntables along the south wall of the north storage basin and along the north wall of the middle basin for entrances into each storage row. The turntables are limited to a maximum load of 500 lb. The storage rows in each basin are defined by 1-ft-wide concrete dividers, 2-1/2 ft high and extending the full width of the basin, except for a 1-ft 3-in.-wide area where the turntables are located. The concrete dividers have a 1-ft edge-to-edge spacing. Figure 8 shows the storage rows in the bottom of the basin and the 1-ft wide concrete dividers at the water level. The north and middle basins each have about 500 yokes: 17 or 18 per row for 29 rows.

Figure 7.   Cask Load Bar

Hanger suspended
in a row

Slot in floor grating

Aluminum-clad lead plate

Fiberglass floor grating

Concrete dividers
at top of basin

Typical pillar supporting
upper concrete dividers
at center of basin length

Concrete dividers
on basin bottom

12"

12"

30"

One foot wide rows for storage
of suspended fuel units and buckets

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(9-88)
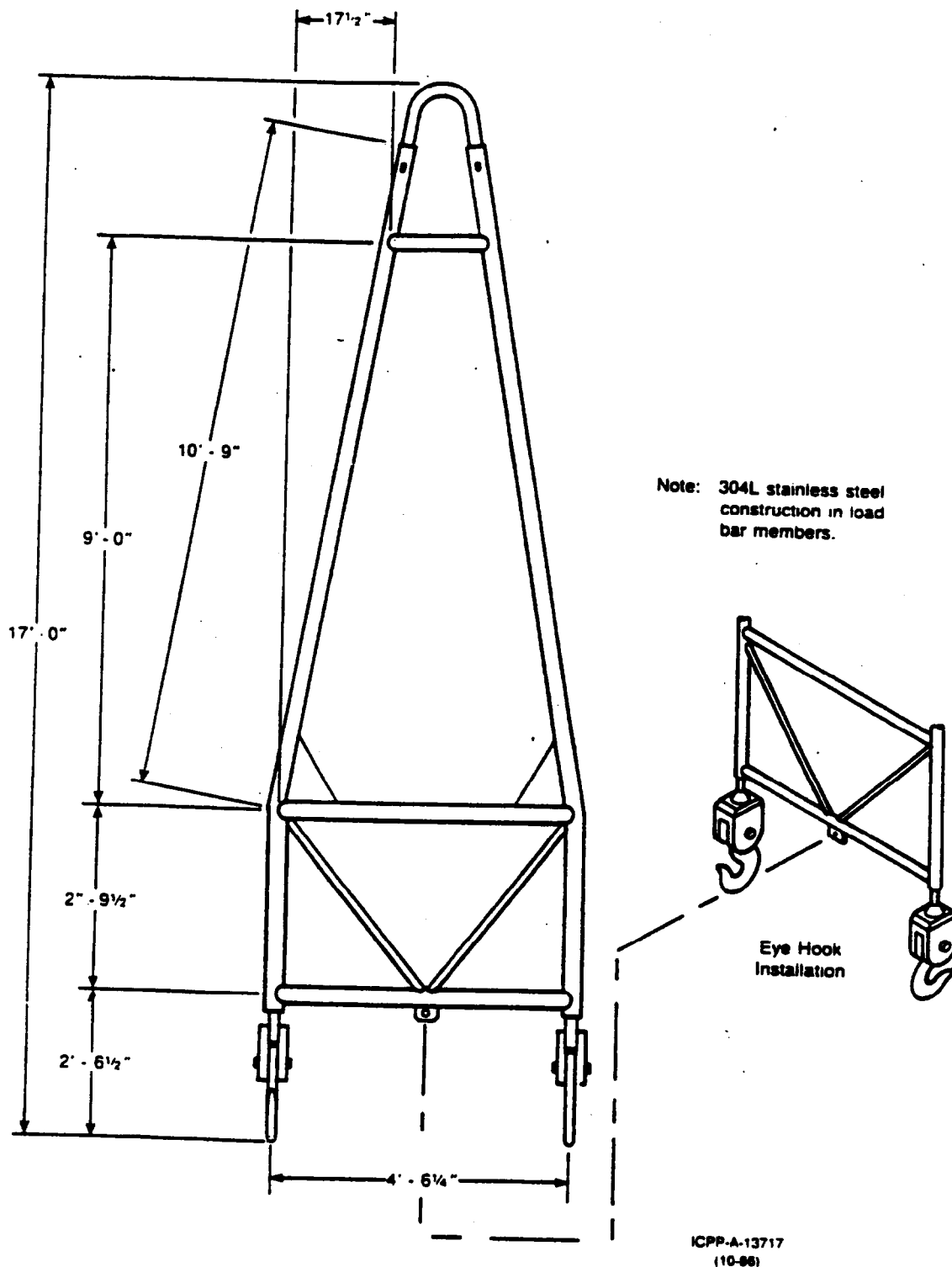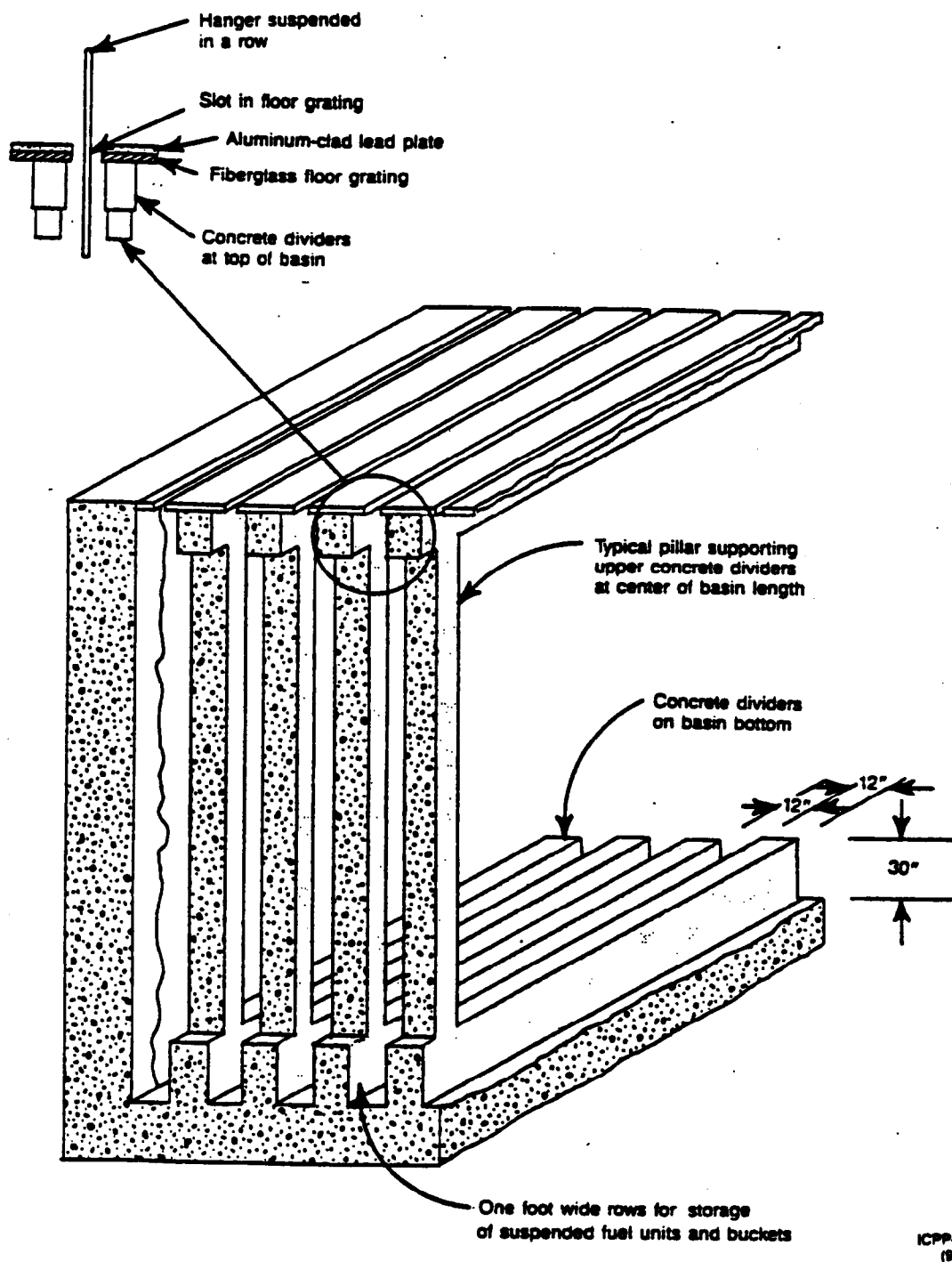
Figure 8. North/Middle Basin Concrete Dividers

3.4.1.1 <u>Monorail Yokes</u>. Various yokes have been used for storage of fuel on hangers in the north and middle basins. Some yokes have hooks on the end to support single components (as clusters), while others have double hooks to support specially designed buckets. The elevations of the support hook and the lower set of bumpers varies with yoke design. Figures 9 and 10 are representative of the two yoke types. The two yoke designs in service are (1) the ECF hook, and (2) the STR hanger. There are carbon steel and stainless steel versions of both of these types in service. Each of these yokes is similar at the top with four rollers (two on each side of the rail) and one-foot horizontal extension arms, or bumpers, designed to space the yokes and maintain adequate separation for criticality safety.

Bumpers are also installed near the bottom of the hanger. The storage configuration is arranged such that only yokes of the same type (bumpers at the same elevation) are stored in the same row or an empty yoke is placed between yokes of different types to ensure criticality safety. The north and middle basin monorail systems are inspected quarterly to ensure that the storage configuration is maintained in this manner.

The ECF hook, shown in Figure 9, is constructed of Type 304 stainless steel or galvanized carbon steel and has a single extension hook.
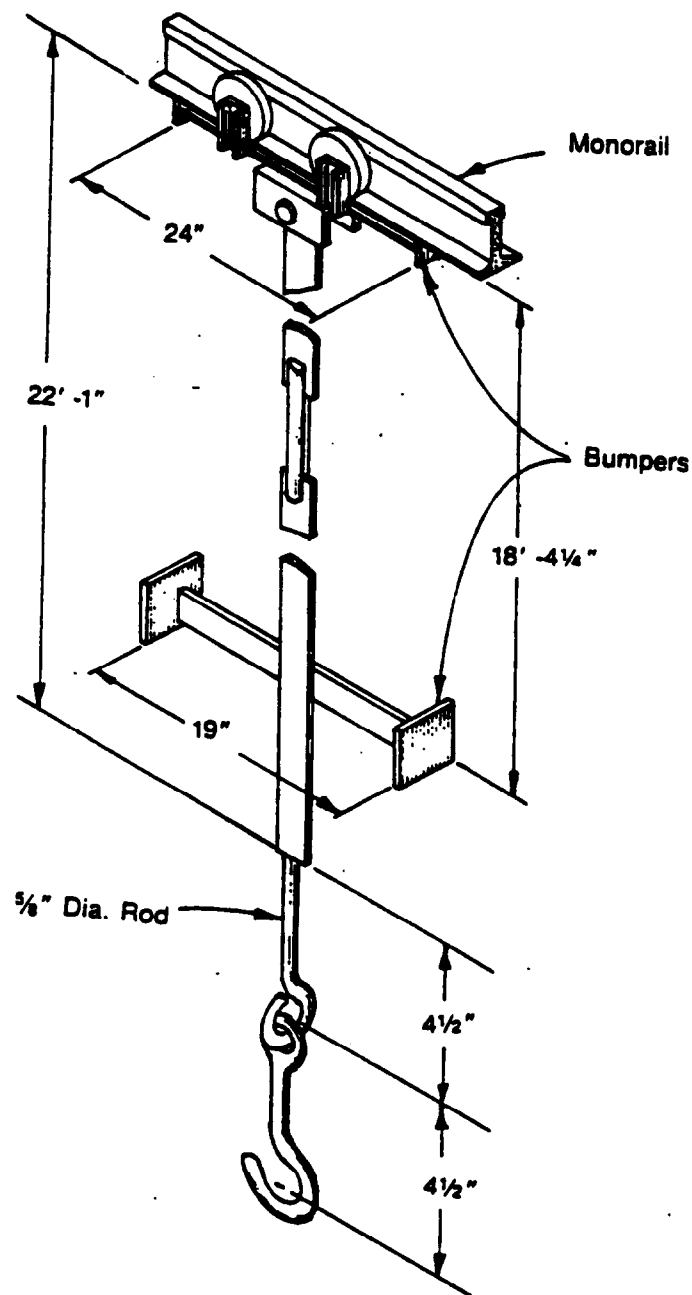
Figure 9. Monorail Hanger - ECF Hook

The STR hanger, constructed of carbon steel, has a double hook, as shown in Figure 10.

3.4.1.2 **Monorail Storage Buckets**. Over the 25 years prior to 1980, several different types and sizes of buckets have been used to support fuel from the monorail system. Operational considerations (such as resistance to corrosion) led to the replacement of older aluminum buckets with more corrosion-resistant stainless steel buckets.

A generic stainless steel bucket, shown in Figure 11, is 8-1/2 in. by 10-1/2 in. with lengths of both 22 and 36 in. It is constructed of Type 304 stainless steel and is supported in the fuel storage basin on the STR hanger, as shown in Figure 10. Other buckets may be used for special fuel types, but specific review and approval is required for new designs.

3.4.2 **Fuel Storage Racks**

Fuel is stored in the storage basins and the FECF (adjacent to the south basin) using three different types of storage racks:

- Aluminum RK-SF-901

- Fort Belvoir ("ALCO" rack)

- Stainless steel RK-SF-900.
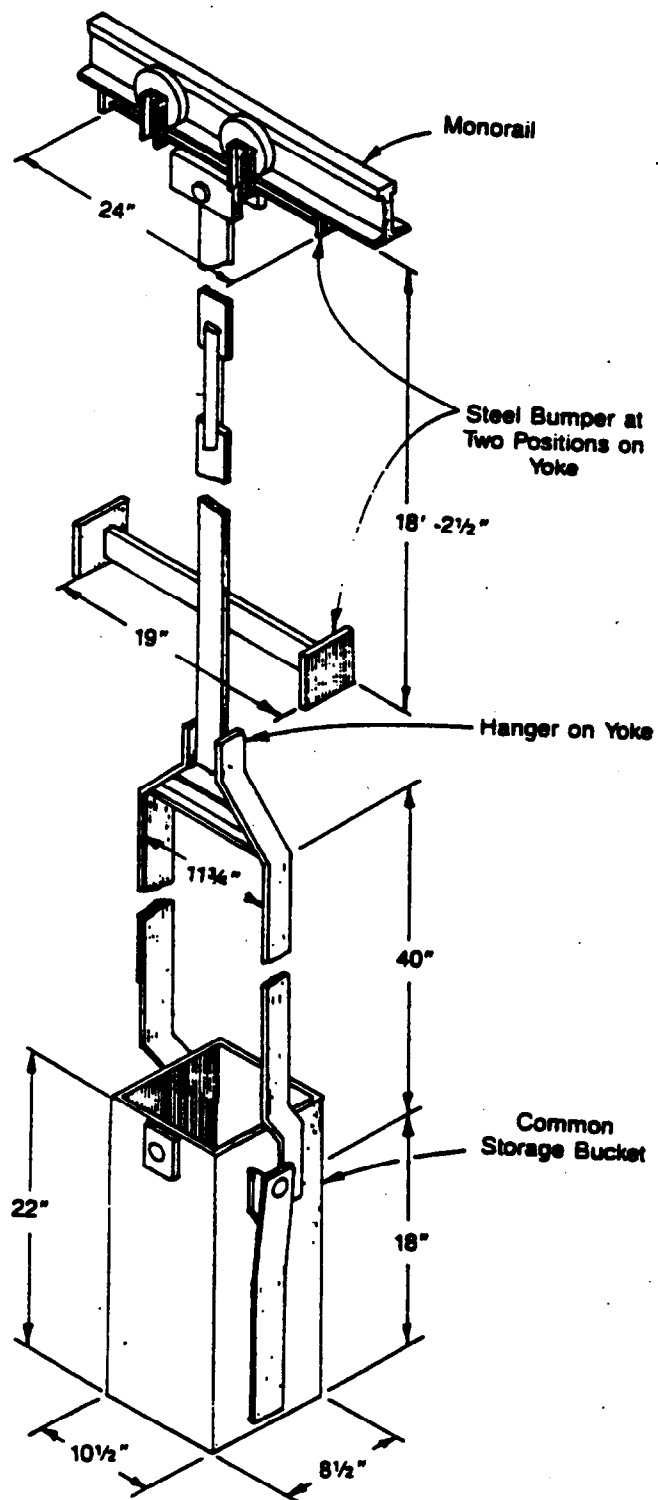
Figure 10. Monorail Hanger - STR with Typical Storage Bucket

22-36"

10½"

8½"
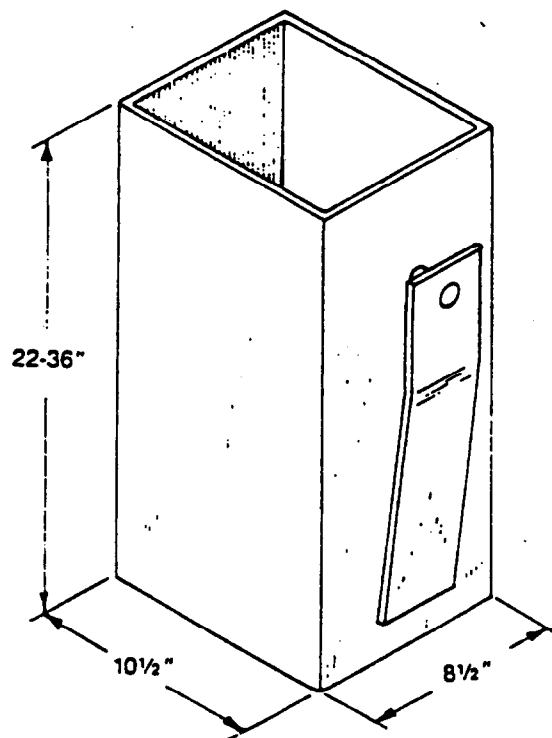
Rectangular Bucket

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(8-88)

Figure 11. Typical Monorail Storage Bucket Designs

3.4.2.1 **Aluminum RK-SF-901 Rack.** This aluminum rack is shown in Figure 12. The exterior dimensions of the rack are 113 in. in length, 74-5/8 in. in width and 67-5/8 in. in height. The estimated weight of the empty rack is 4000 pounds. The rack structural members, top and bottom plate, frame and tube supports are all constructed of aluminum alloy 6061-T6. There are 92 storage positions, i.e., tubes, constructed of 6-in. Schedule 40 aluminum pipe (6.625-in. OD and 6.065-in. ID) 63 in. long. The center-to-center spacing of the tubes is 8.09 in. along the length of the rack (2.03 in. edge-to-edge). Diagonally, the center-to-center spacing between tubes is 8.17 in. (2.13 in. edge-to-edge).

The rack structure provides an 8-in.-wide lip between the rack edge and the peripheral rack positions. In an array of these racks, touching at the edges, each rack will be neutronically isolated from its neighboring racks. Due to the large lip region of the rack, the individual racks do not interact to any great degree with other rack types or fuel pieces brought up against the edge.

All of the RK-SF-901 racks are dedicated to aluminum fuel (units or cans) storage.

3.4.2.2 **Fort Belvoir Rack.** The Fort Belvoir fuel rack, also called the ALCO rack, is shown in Figure 13 and is located in the FECF. It was originally used for storage of canned EBR-I Mark IV fuel rods. This fuel was removed from storage and shipped to another facility for reprocessing. At the present time, there is Peachbottom fuel in the FECF. The overall rack dimensions are 46 in. in length by 36 in. in width and 30 in. high with 20 storage positions in a 4 x 5 array. The rack is constructed of 304 stainless steel, and the storage positions are 5-in.-OD tubes with a flame-coated cadmium plating on the surface.
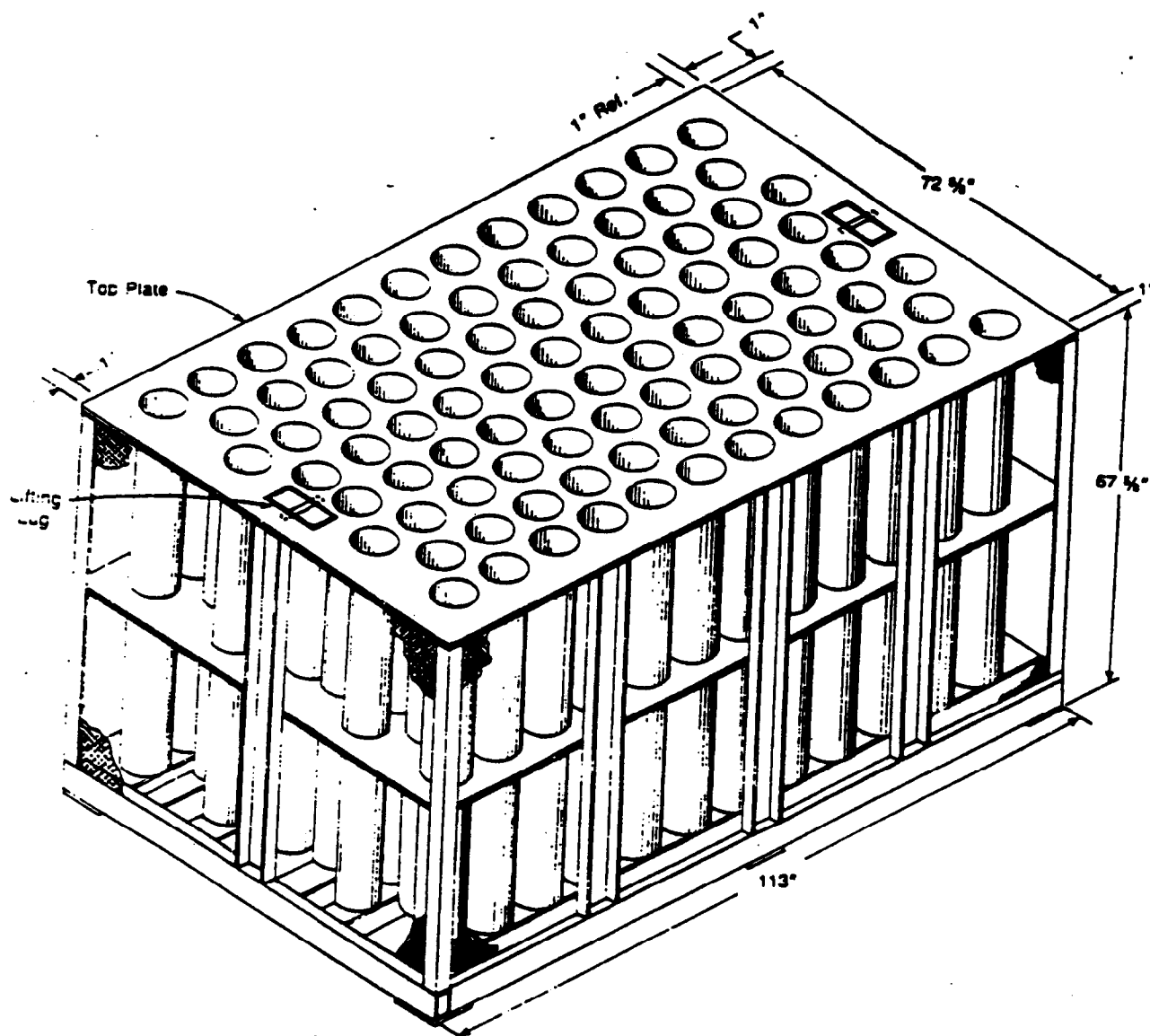
Figure 12. RK-SF-901 Aluminum Fuel Storage Rack
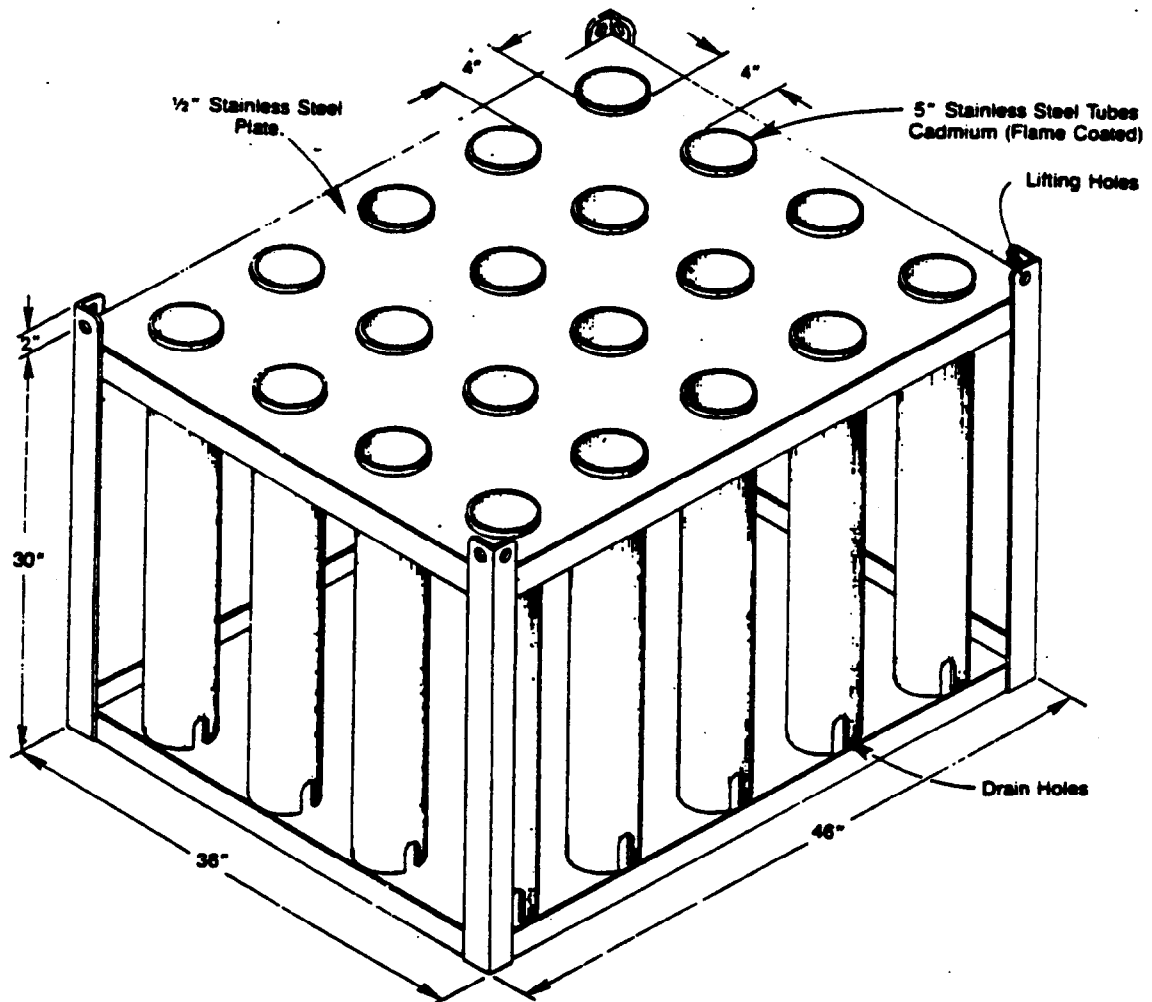
Figure 13. Fort Belvoir Fuel Storage Rack

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(11.95)

1½" x 1½" x 2'

30'

12'

Storage Positions

Horizontal Stabilizer Extensions

Concrete Dividers of North Basin
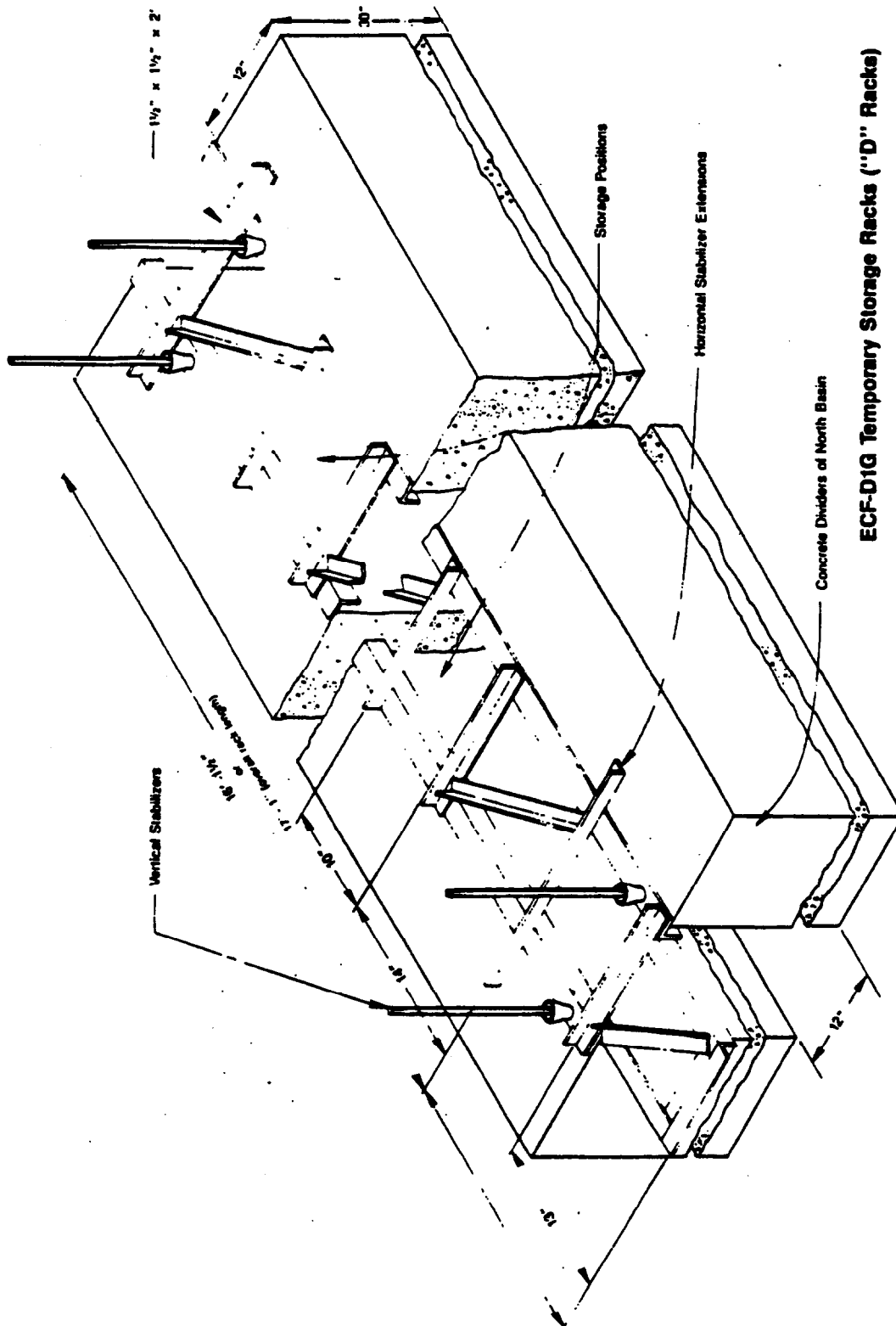
ECF-DIG Temporary Storage Racks ("D" Racks)

Vertical Stabilizers

12'

Figure 14.   Temporary DIG-ECF "D" Fuel Storage Racks.

3.4.2.3 "D" Racks. D1G fuel was stored in temporary racks in rows 2 through 6 of the north storage basin. This mode of storage was developed because the aluminum hangers used with D1G fuels experienced accelerated corrosion. These racks, shown in isometric view in Figure 14 are called ECF-D1G Temporary Storage Racks and are fabricated of Type 304 stainless steel. They rest on dividers that define the storage rows in the north storage basin and provide 24-in. center-to-center spacing in the storage positions. The racks are of two lengths, 16 ft 1-1/2 in. and 17 ft 1 in., and are constructed of 2-in. by 2-in. by 1/4-in. angle. Horizontal outriggers, made of 1-1/2 in. by 1-1/2-in. by 1/4-in. angle, are welded to the rack at approximately 8-ft intervals to provide stability against the rack tipping. Two 2-in. by 1-in., schedule 40 reducers, made of Type 304 stainless steel, are welded at each end of the racks into which 20-ft rods can be placed vertically to wedge against the surface grating to prevent the rack from being lifted.

In addition to storage of D1G-1 half-clusters, cans of S3G-3 fuel were also approved for storage in the "D" racks. All fuel has been removed from the "D" racks.

3.4.2.4 RK-SF-900 Racks. The stainless steel RK-SF-900 racks are 7 ft 6-3/4 in. long by 4 ft 6-1/2 in. wide, with 15 storage positions in a 3 x 5 array, as shown in Figure 15. They are constructed of Type 304 stainless steel, with 9-3/4-in.-square storage positions, 74 in. tall. Each of the 15 storage positions has a lid which remains closed (down) except when fuel is loaded or unloaded into a position, or when the rack position is opened for training purposes or for physical inventory and inspection of the contents. The edge of the rack top plate is at least 4 in. from the edge of the peripheral rack position. Thus, all of the positions in a two-dimensional array of these racks are spaced as in the single rack with no spacing discontinuity at the individual rack boundaries.

These racks were originally designed and built for storage of zirconium fuels from ECF but have also been used for the storage of other fuel materials and types such as EBR-II fuel element containers in rack inserts, GETR filters, Buffalo Pulstar (SUNY) fuel cans, and stainless steel clad TRIGA, SNAP, AI, TORY-IIA, SIR, and GFO fuel types.
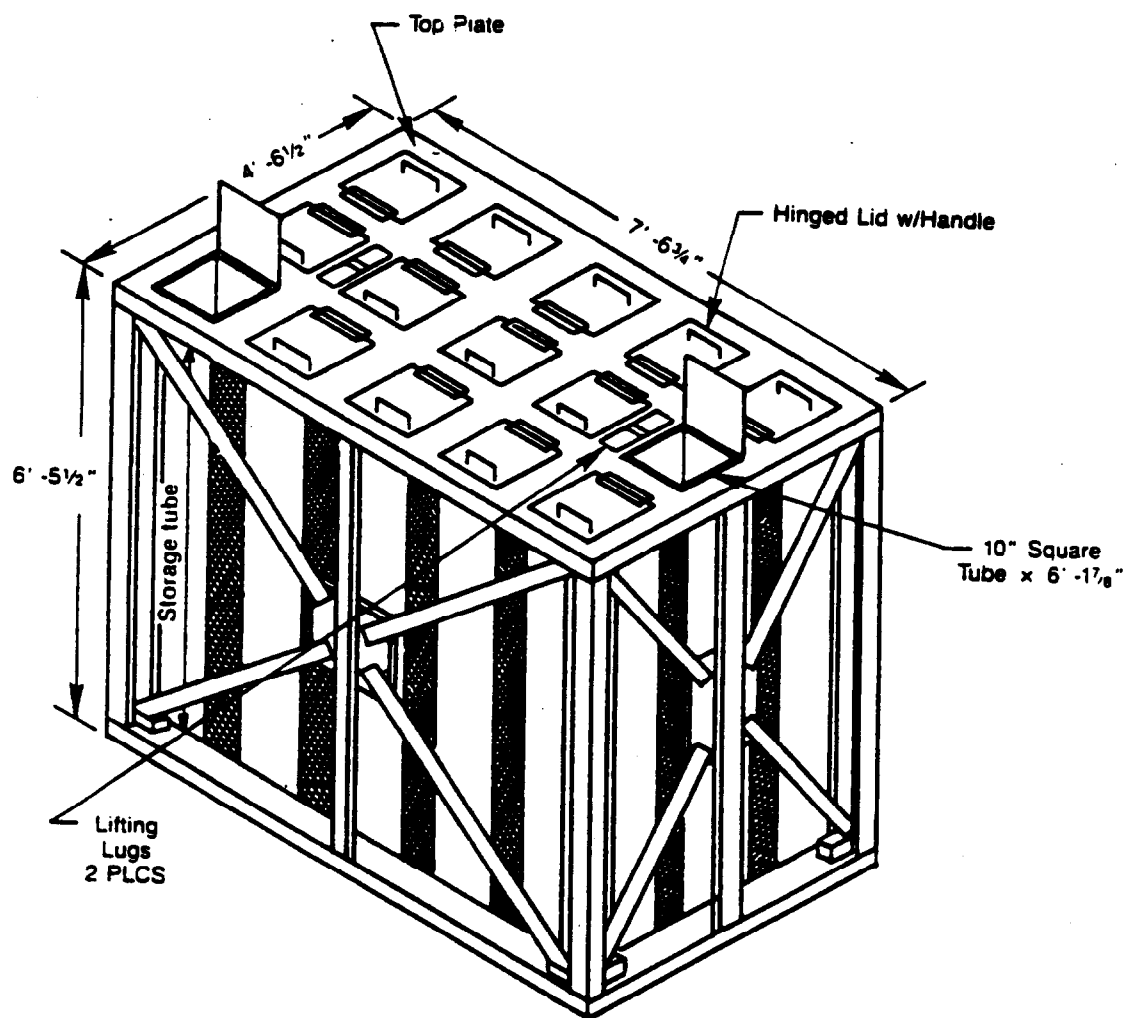
Figure 15. RK-SF-900 Stainless Steel Fuel Storage Rack

3.5 WATER TREATMENT SYSTEMS

Various systems have been installed at the CPP-603 underwater fuel storage facility to maintain water quality. The overall water treatment system is shown in a block diagram, Figure 16. Line drawings for the individual water treatment systems are as follows:

1. Reverse-Osmosis Demineralization, Figure 17

2. Multimedia Filters, Figure 18

3. Old and New Ion-Exchange Systems, Figures 19 and 20

4. Chloride Removal System, Figure 21

5. Regenerant Makeup, Figure 22

6. Ultraviolet Light Sterilization, Figure 23.

The chemical makeup and cask rinse water supply system, consisting of VES-SF-103 and -104, the vessels used for the regenerant makeup for the old ion exchange system prior to the installation of the new regenerant and ion exchange systems, is shown in Figure 24.

The design details of the vessels associated with the various cleanup systems are presented in Table II. The design details of the hot waste tank, VES-SFE-126, and of the sludge storage tank, VES-SFE-106, are also included in this table, although these tanks are part of the waste management system rather than the water treatment system at CPP-603. The operational and design data for the pumps are listed in Table III.

3.6 INSTRUMENTATION

Proper operation of the fuel storage process and basin water treatment process requires the use of control and monitoring instrumentation. A complete listing of the instrumentation at the CPP-603 facility is available in the ICPP instrument database. Instrumentation is categorized based on the functions of the systems it serves. Instrument categories are designated as Group I, II or III.
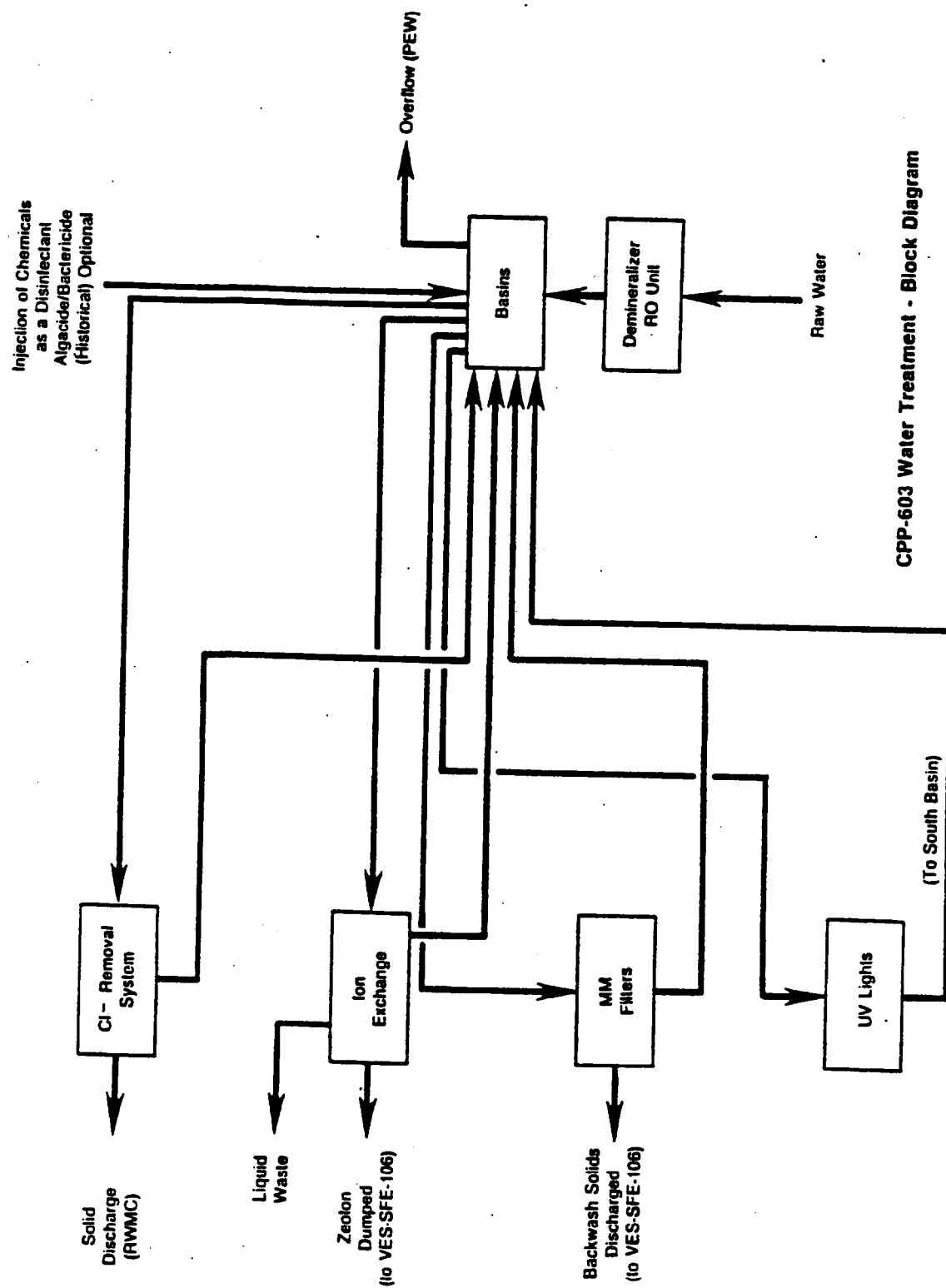
Figure 16. CPP-603 Water Treatment - Block Diagram
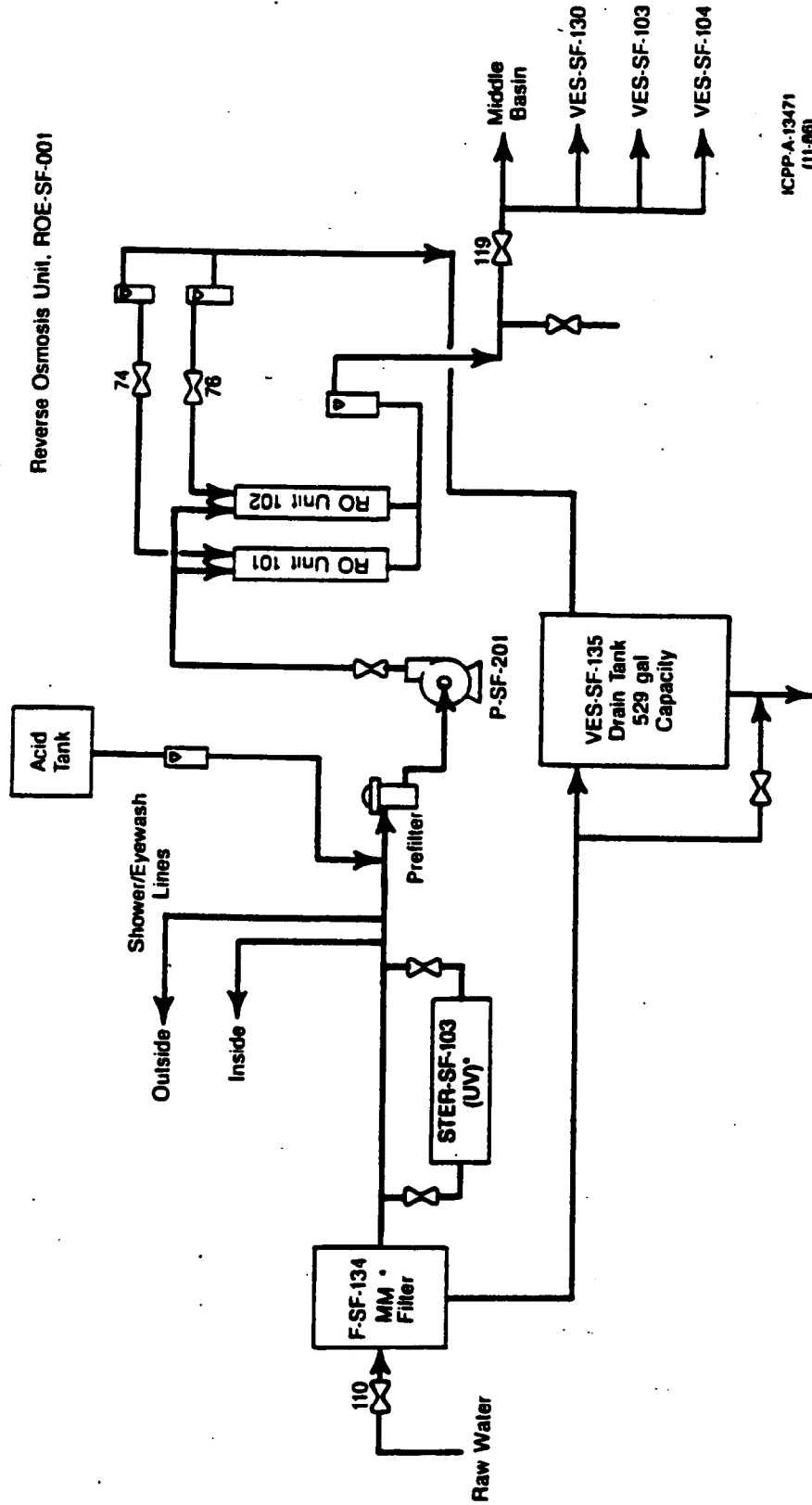
Figure 17. CPP-603 Reverse Osmosis Unit - Raw Water Demineralization

* Ultraviolet light sterilizer (UV)
• Multimedia (MM)

Figure 18. CPP-603 Pressurized Multimedia Filter System

LS = Level Switch
RM = Radiation Monitor
RI = Rate Controller
FI = Flow Indicator
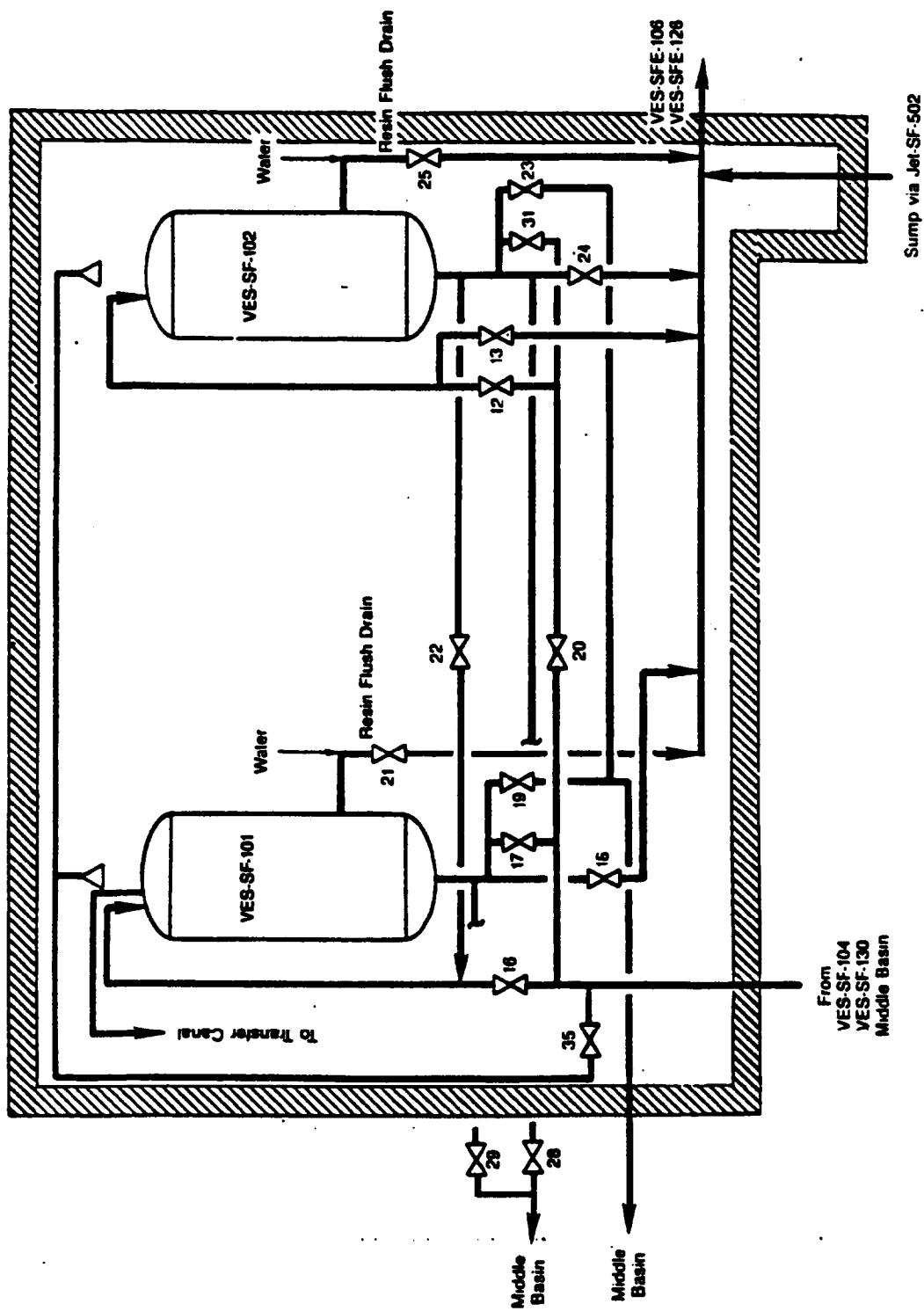
Figure 19. CPP-603 Old Ion-Exchange System
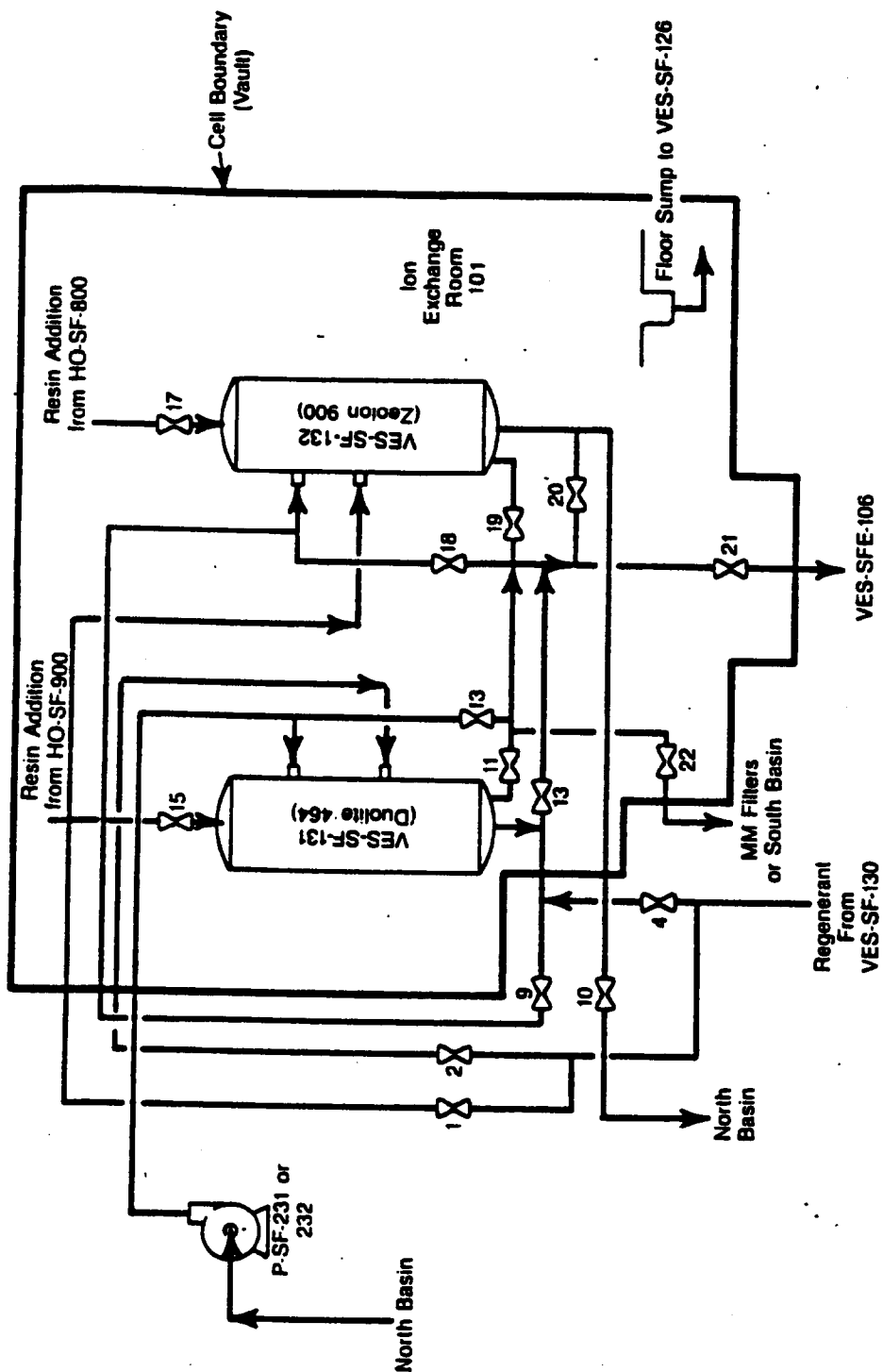
Figure 20. CPP-603 New Ion-Exchange System

Figure 21. CPP-603 Chloride Removal System
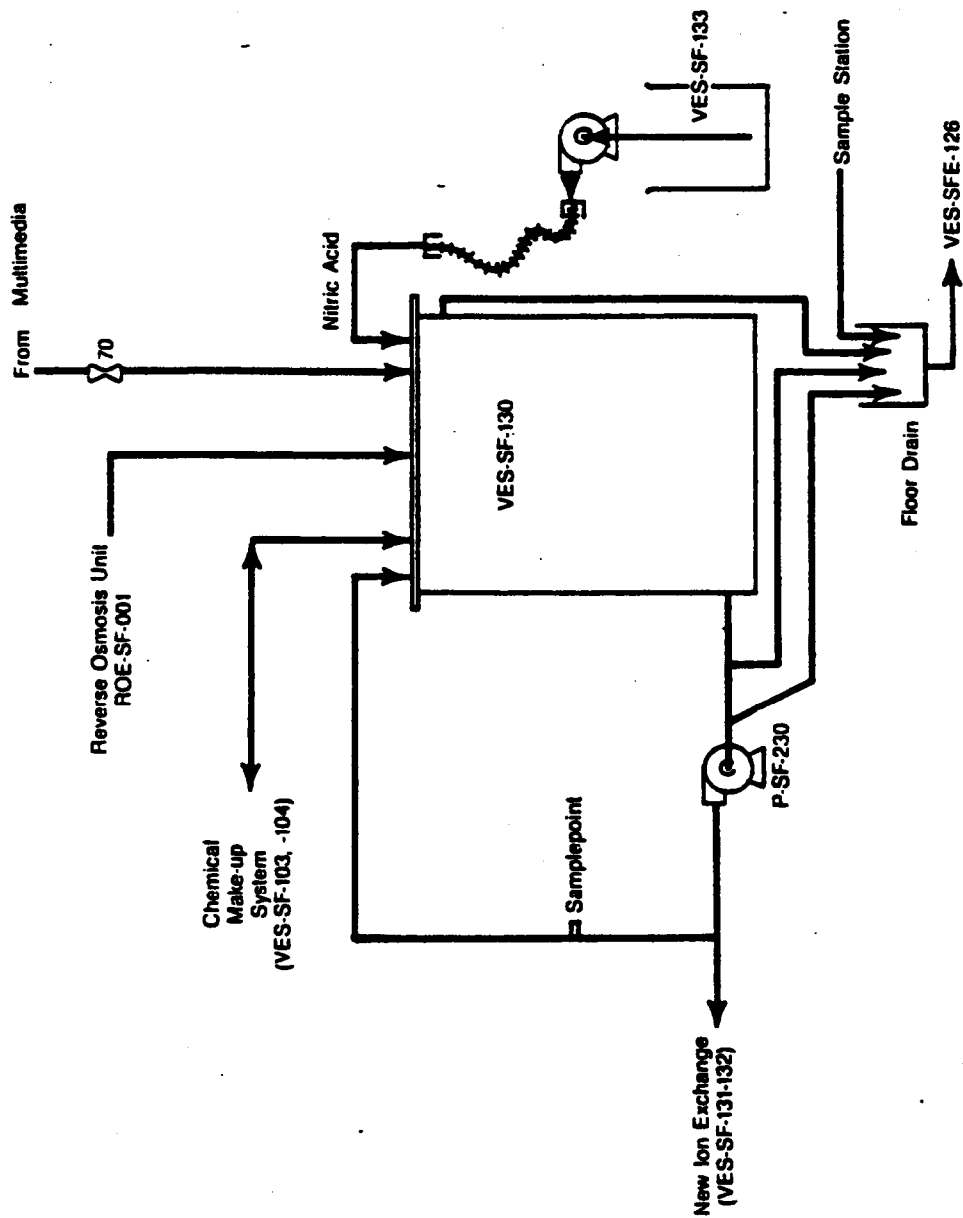
Figure 22. CPP-603 Regenerant Make-up System

Figure 23. CPP-603 Ultraviolet Light Purification System
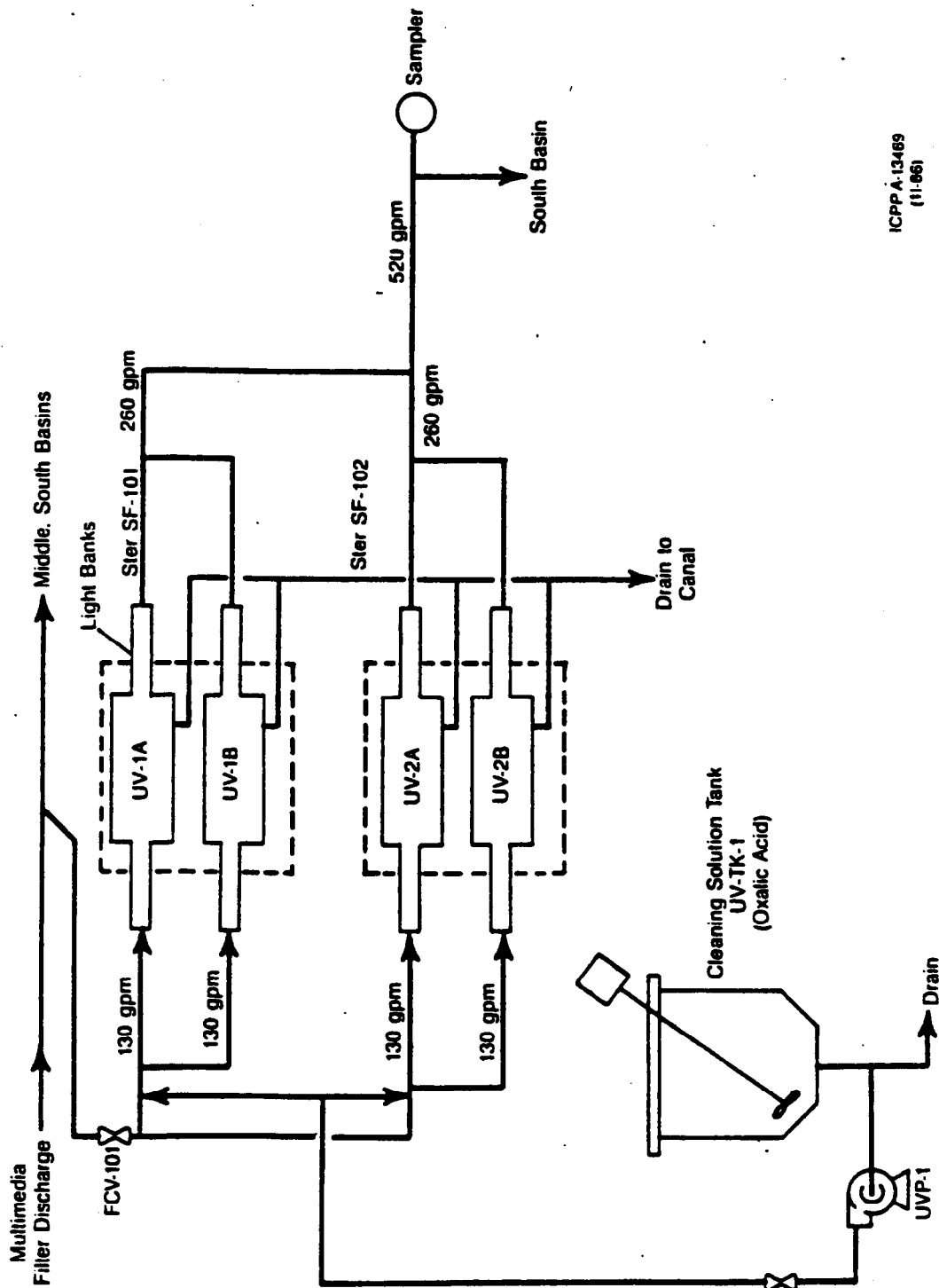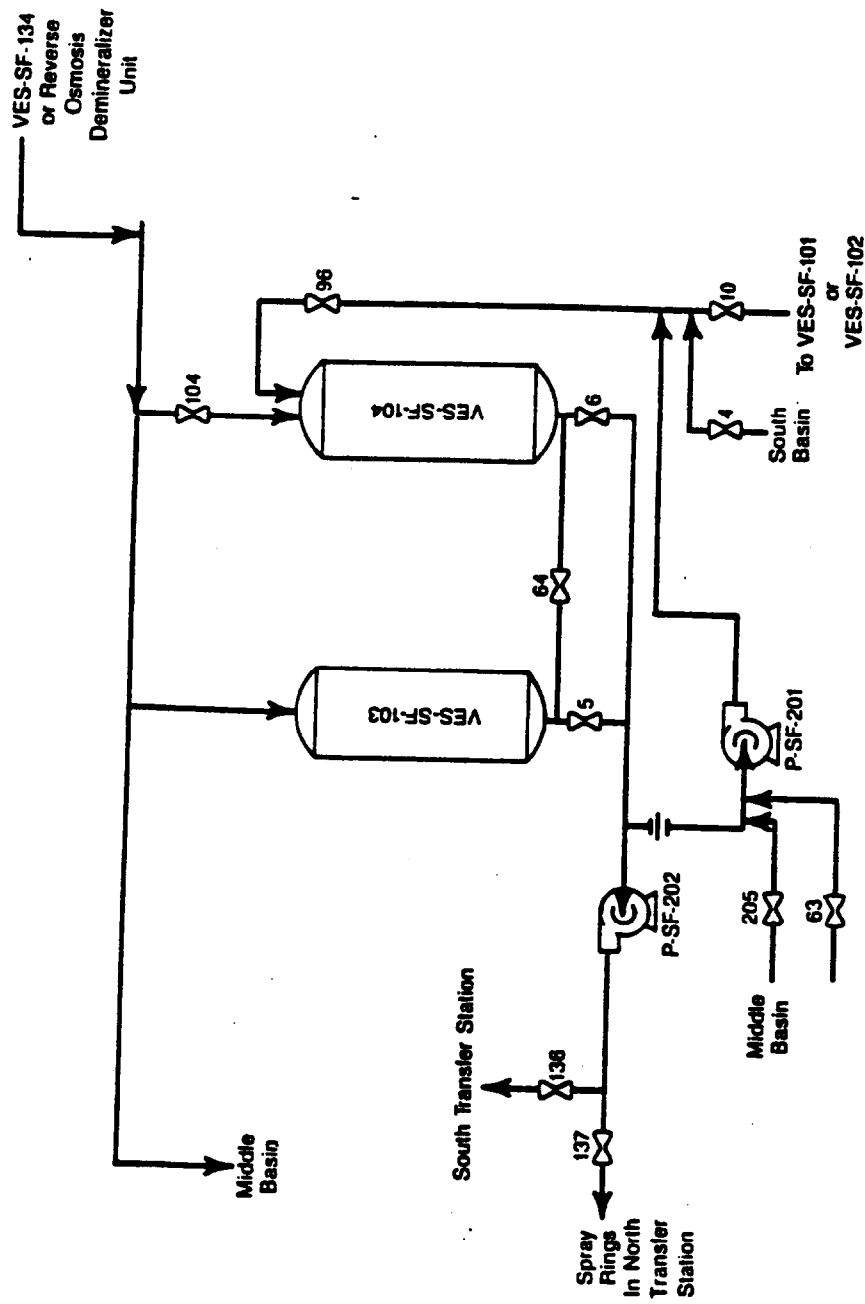
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Figure 24. CPP-603 Chemical Makeup/Cask Rinse Water System

Table II. Basin Water Cleanup Equipment - Vessels

Parameter	F-SF-113/114/115	VES-SF-108	VES-SF-109
Name	Pressurized sand filter units "A", "B" and "C"	Filter backwash holding tank	Clarifier
Description	72-in.-OD x 66-in. shell height 28.3 ft²/filter cell	120 in. OD x 151 in. high Vertical	144 in. OD x 154 in. high Vertical
Material	Carbon steel with epoxy lining Filter media (44 in.): 3 in. of 1/4 to 1/2 in. pea gravel 5 in. of 1.4 to 2.4 mm garnet (filter medium) 18 in. of 0.4 to 0.5 mm garnet (filter medium) 18 in. of 0.66 mm anthracite	Carbon steel with PVC lining	Carbon steel with PVC lining
Design pressure	150 psig	Atmospheric	Atmospheric
Design temperature	70°F	Ambient	Ambient
Capacity	12 gpm/ft²	6500 gal	5200 gal
Operating temperature	Ambient	Ambient	Ambient
Operating pressure	60 psig	Atmospheric	Atmospheric

Table II. (Contd.) Basin Water Cleanup Equipment - Vessels   Page 2 of 4

Parameter	VES-SF-119	VES-SF-121	VES-SF-122	VES-SF-123
Name	Chloride removal reverse osmosis unit feed tank	Chloride removal reverse osmosis unit	Chloride removal evaporator feed tank	Chloride removal reverse osmosis scraped surfaces evaporator
Description	2 ft OD x 3 ft high vertical tank, dished bottom, flanged cover	4 ft x 10 ft x 6 ft high	3.5-ft-OD x 6-ft high tank, dished bottom with flanged cover	5 x 13 x 9 ft high
Material	Fiberglass reinforced plastic	Tank: Type 304 stainless steel with PVC lining	Fiberglass reinforced plastic	Type 316 stainless steel
Design pressure	Atmospheric	500 psig	Atmospheric	Atmospheric
Design temperature	Ambient	Ambient	Ambient	250°F
Capacity	76 gal	25 gpm	457 gal	25 gpm
Operating temperature	Ambient	Ambient	Ambient	150-200°F
Operating pressure	Atmospheric	400 psig	Atmospheric	Atmospheric

Table II. (Contd.) Basin Water Cleanup Equipment - Vessels   Page 3 of 4

Parameter	VES-SF-106	VES-SF-101	VES-SF-102	VES-SF-103/104	VES-SFE-126
Name	Sludge storage tank	Old ion exchange vessel	Old ion exchange vessel	Chemical and water makeup tanks	Hot waste tank
Description	10 ft OD x 42 ft long horizontal	3 ft OD x 8 ft tall	3 ft OD x 8 ft tall	4 ft OD x 12 ft tall	7 ft OD x 14 ft long horizontal
Material	Type 304 stainless steel	Type 304 stainless steel	Type 304 stainless steel	Type 304 stainless steel	Type 304 stainless steel
Design pressure	100 psig	100 psig	100 psig	100 psig	15 psig
Design temperature	Ambient	Ambient	Ambient	Ambient	120°F
Capacity	25,000 gal	423 gal	423 gal	1000 gal	3400 gal
Operating temperature	Ambient	Ambient	Ambient	Ambient	Ambient
Operating pressure	Atmospheric	50 psig	50 psig	Atmospheric	Atmospheric

Table II. (Contd.) Basin Water Cleanup Equipment - Vessels   Page 4 of 4

Parameter	F-SF-113/114/115	VES-SF-108	VES-SF-109
Name	New ion exchange vessel	Regenerant makeup tank	Sand for raw water (Not in service)
Description	5-ft-6-in.-OD x 8-ft-1-in. height	9-ft-OD tank shell x 9-ft height	
Material	304 L stainless steel	304 L stainless steel	
Design pressure			
Design temperature	Ambient		
Capacity	1421 gal	4000 gal	
Operating temperature	Ambient		
Operating pressure			

Table III. Basin Water Cleanup Equipment - Pumps

Parameter	P-SF-214/215	PS-SF-216/217	P-SF-219
Name	Recirculation pumps (feed to filters)	Transfer pumps from filters to basin	Chloride removal reverse osmosis unit feed tank pump
Description	Centrifugal Horizontal 30 hp	Centrifugal Horizontal 0.33 hp	Centrifugal 3 hp
Material	Carbon steel with epoxy lining	Carbon steel	316 stainless steel
Design pressure	85 psig	7.5 psig	40 psig
Design temperature	Ambient	Ambient	Ambient
Capacity	500 gpm at 85 psig	30 gpm	25 gpm
Operating temperature	Ambient	Ambient	Ambient
Operating pressure	37 psig	6.5 psig	35 psig

Table III. (Contd.) Basin Water Cleanup Equipment - Pumps   Page 2 of 3

Parameter	P-SF-222	P-SF-203/213
Name		
Description	Chloride removal evaporator feed pump	Old ion exchange system feed pump
	Positive displacement metering 3/4 hp	Centrifugal 7.5 hp
Material	Type 316 stainless steel	Type 316 stainless steel
Design pressure	10-psig discharge	100 ft H_2O
Design temperature	Ambient	Ambient
Capacity	2 gpm	50 gpm
Operating temperature	Ambient	Ambient
Operating pressure	10 psig	60 psig

Table III. (Contd.) Basin Water Cleanup Equipment - Pumps   Page 3 of 3

Parameter	P-SF-231/232	P-SF-230	P-SF-202
Name			
Description	Primary/auxiliary feed pump to new ion exchange system	Regenerant feed pump to new ion exchange system	Cask spray ring (in middle basin) feed pump
	Wilfley centrifugal	Wilfley centrifugal	Wilfley centrifugal
Material	Type 316 stainless steel	Type 316 stainless steel	Type 316 stainless steel
Design pressure	90 psig	90 psig	100 psig
Design temperature	Ambient	Ambient	Ambient
Capacity	200 gpm	300 gpm	50 gpm
Operating temperature	Ambient	Ambient	Ambient
Operating pressure	60 psig	70 psig	60 psig

Group I instruments are those that perform a primary role in monitoring and/or controlling parameters necessary for compliance with the operational safety requirements identified in the safety evaluation for this process. Since those operations that can lead to a criticality or excessive radiation doses in this facility are related to fuel handling, there are very few instruments designated as Group I. Group II instruments are those whose failure or maloperation will not lead to operation outside of the identified OSRs but which are judged important for the protection of employees, the general public or the physical facility. The Group III instruments have little or no safety significance but are necessary to ensure operability or efficiency of the processes. The Group I instruments identified for this process are listed in Table IV.

The Group I instrumentation at the CPP-603 underwater fuel storage facility includes a basin water-level-indicator, a criticality alarm system (CAS) and five continuous air monitors (CAMs). The CAS detectors also function in a dual role as remote area monitors (RAMs). As part of the CAS, the detectors activate the emergency evacuation system if two or more detectors simultaneously indicate a high radiation field of 1 R/hr or greater.

3.7 HEATING AND VENTILATION

The CPP-603 facility and the associated personnel area in CPP-603 are equipped with heaters for space heating when needed. The heating equipment in the CPP-603 building consists of wall-mounted units, supplied with steam and equipped with blowers for forced-air heating. These units are located along the truck and crane bays. The fuel storage basins are not heated, other than by decay heat generation from the contained fuel materials. Portable electric heaters (for space heating) are located in the north basin area, and are used during the winter months to prevent condensation on the facility walls.

The CPP-603 basin facility is not generally served by a contamination-control/filtered-exhaust type ventilation system. At CPP-603, there is no control on airflow paths in the facility, and the lack of sealing in the superstructure and the large number of access

Table IV. CPP-603 Underwater Fuel Storage Facility Group I Instrumentation[a]

Instrument	Function	Instrument Range
LA-SF-002 (Basin Liquid Level)	Detect loss of water	0-18 in. H_2O
Five Criticality Alarm system (CAS) Detectors over transfer pits and storage basins	Functions as a dual purpose Criticality Alarm System (CAS) - Remote Area Monitor (RAM) system monitoring radiation levels above the fuel transfer pits and storage basins	0.1 to 10^4 mR/hr
Five continuous air monitors (CAMs)	Monitor the airborne radioactivity levels in the air within the CPP-603 building	50 - 50,000 cpm 0-10^3 cpm 10^3-10^4 cpm 10^4-10^5 cpm

[a] Group I Instruments - Instruments that perform a primary role in monitoring and/or controlling parameters to ensure operation of the facility within the safety envelope as defined by the operational safety requirements (OSRs).

doors (personnel and vehicle) permit uncontrolled intake from, and exhaust to, the outside atmosphere. The lack of filtration permits the inflow of dust and dirt into the facility and, in the event of generation of volatile fission products (i.e., from a criticality accident), an unfiltered release of radioactive gases to the outside environment.

There are two roof-mounted exhaust fans in the building, and the ion-exchange systems are either equipped with an H&V system (NIES, i.e., "new ion-exchange system") or HEPA-filtration (OIES, i.e., "old ion-exchange system").

4. INTERCONNECTIONS

Interconnections between the basin underwater storage system and its supporting systems are shown schematically in Figure 25. The individual vessel interconnections are listed in Appendix A. The purpose of this listing is to provide a complete overview and to present data for evaluating the interactions between the basin storage system and its supporting environment. Aside from the basin proper and the associated water treatment systems, the principal interconnections are those that supply utilities, such as water, electricity, and steam, and those that remove process wastes. The individual support systems are discussed in other PSD sections.

4.1 UTILITIES

The electrical power for CPP-603 is received from the ICPP substation transformer area (CPP-613). It is then dispersed to the various loads and load centers throughout the CPP-603 area. Emergency power is supplied by a propane-powered generator located in the CPP-603 Irradiated (Dry) Fuel Storage Facility (IFSF) attached to the underwater facility. The only system at the underwater facility served by the generator is the CAS.

The Criticality Alarm System (CAS) is supplied with a backup power supply; which consists of batteries that are maintained by a trickle charger.

Water is obtained from the CPP-603 fire water loop for feedwater to the reverse osmosis demineralization unit, which provides makeup water for the chemical makeup system and for cask rinsing as well as replacement of water losses in the basins due to evaporation. Steam is used in CPP-603 for space heating and for operating steam jets. All steam condensate can be sent to a shallow disposal well in the CPP-603 area. Electric heaters are also used in limited areas of the CPP-603 facility.
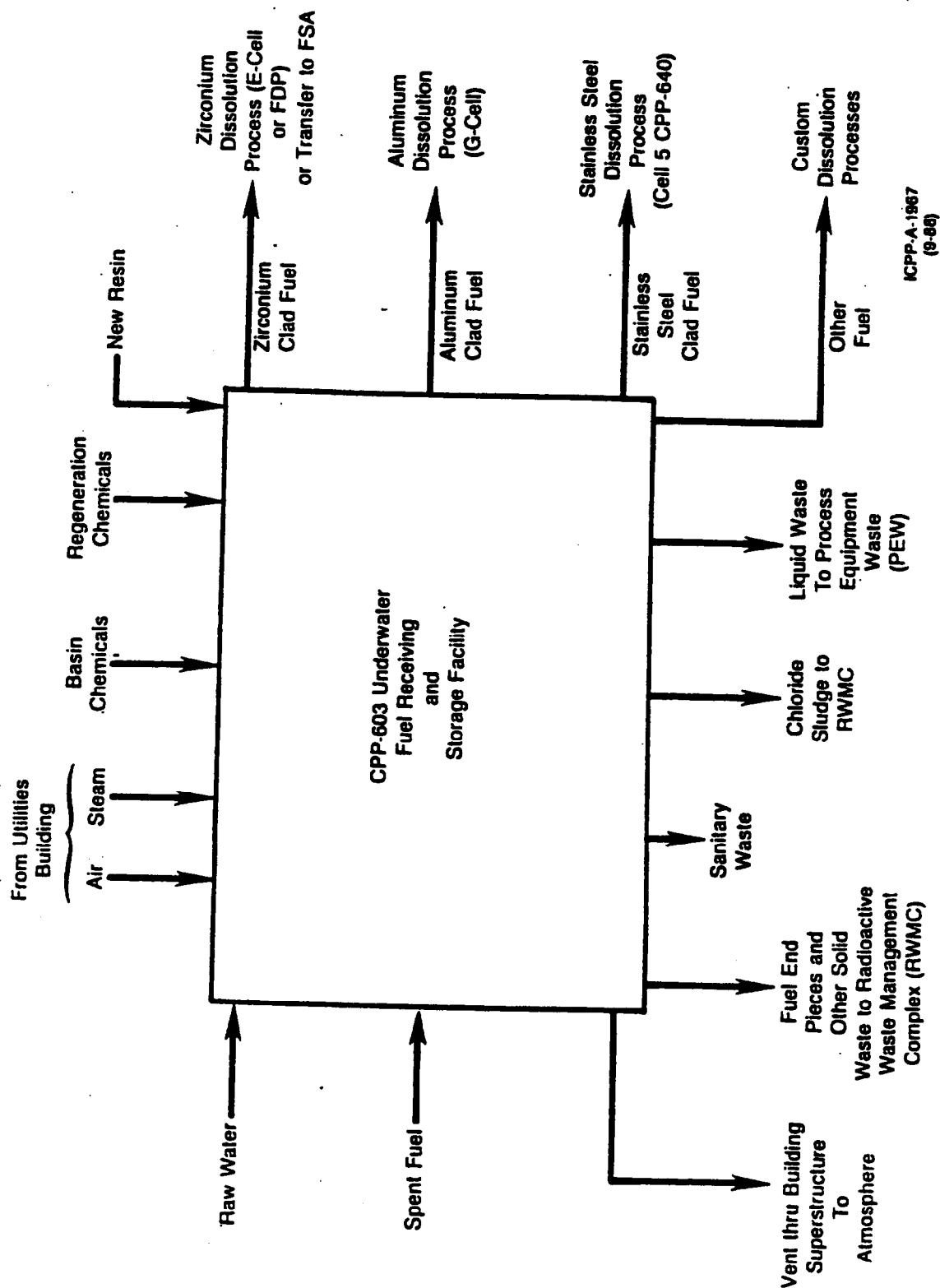
Figure 25. Interconnections with Other Systems

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4.2 WASTE SYSTEMS

Under normal conditions, no gaseous waste is generated in the CPP-603 facility. Moist air that rises from the basins passes directly to the atmosphere by natural convective flow. This flow of air provides the major mechanism for dissipation of heat energy from the stored fuel. Although the air is not processed through a fan and filter system, Continuous Air Monitors (CAMs) monitor for excessive airborne radioactive contamination.

The FECF, essentially abandoned in place with only two canned Peachbottom fuel elements stored there, is equipped with a HEPA-filtered exhaust system that serves as a filtered vent system for the venting of incoming pressurized casks. In addition, all waste receiving and storage vessels for radioactive liquids, such as the sludge storage tank (VES-SFE-106) and the hot waste tank (VES-SFE-126), are equipped with HEPA filters. These provide a filtered exhaust path for air displaced during vessel filling and steam and air sparging activities.

Aqueous wastes that have the potential for containing radioactive materials are either recycled to the basin or processed through the hot waste tank (VES-SFE-126). This tank is a 3400-gallon waste tank. From the hot waste tank, the aqueous waste is processed through the CPP-604 PEW system for evaporative volume reduction and storage with high-level wastes. The major connections to VES-SFE-126 are shown in Figure 26. VES-SFE-126 receives waste from the cask decontamination pad, the sludge storage tank, the CPP-603 building drains, and the IFSF area.

Nonradioactive aqueous wastes, such as service wastes and coolant from heat exchangers, are routed to two shallow dry wells for disposal. The dry well may also receive condensate from the steam heaters. Sanitary wastes are discharged to a septic tank, which discharges to a separate dry well.

Solid wastes consist of (1) rags, shoe covers, paper coveralls, blotting paper, etc., (2) expended ion exchange resin, and (3) filter backwash solids. Solids were also generated by the vacuum operations (sludge from the basin floors) and the chloride removal system (chloride solids) when these systems were in operation.
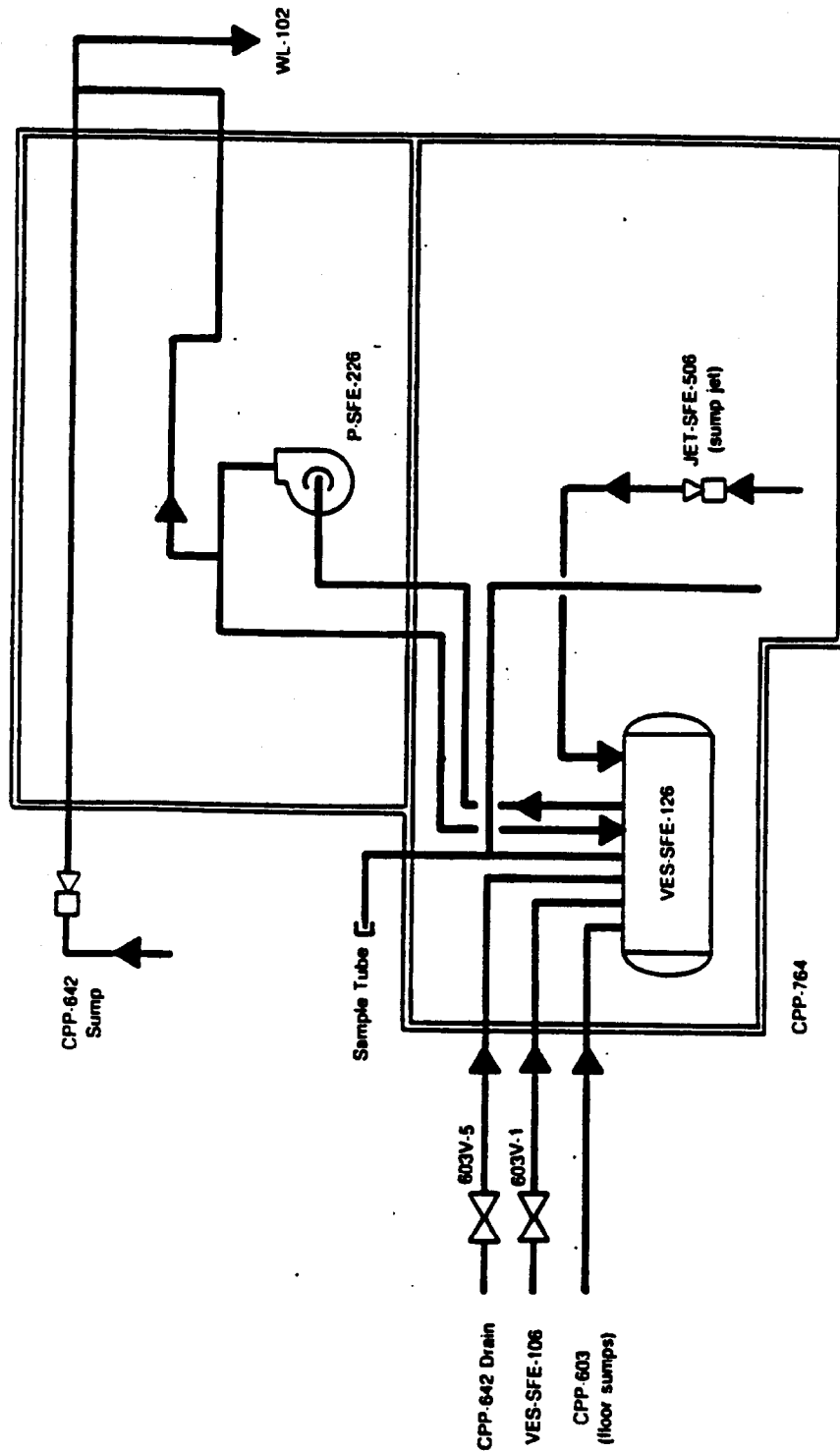
Figure 26. CPP-603 Hot Waste Tank (VES-SFE-126)

The major connections to the 25,000 gallon CPP-603 sludge storage tank, VES-SFE-106, are shown in Figure 27. Spent ion exchange resins are transferred to the sludge storage tank (VES-SFE-106). Previously, sludge was vacuumed from the bottom of the basin and collected in VES-SFE-106. The sludge storage tank served as interim storage for the vacuumed sludge until it was transferred to concrete containers, solidified and shipped to the RWMC. The liquid fraction (i.e., by settling or decanting) can be transferred either to the hot waste tank, VES-SFE-126, or to PEW (via WL-102) for disposal. The tank is also equipped with a manhole and several sampling and monitoring lines extending up to the ground level and an air vent line with a Demister, HEPA filter and deentrainment vessel. The manhole is shielded with a concrete plug and lead plugs are provided for the sampling and monitoring lines.

In 1986-87, a sludge removal operation, performed by an outside contractor, emptied the -106 vessel. The sludge material (resin, etc.) was solidified, packaged and shipped out to the RWMC for disposal.
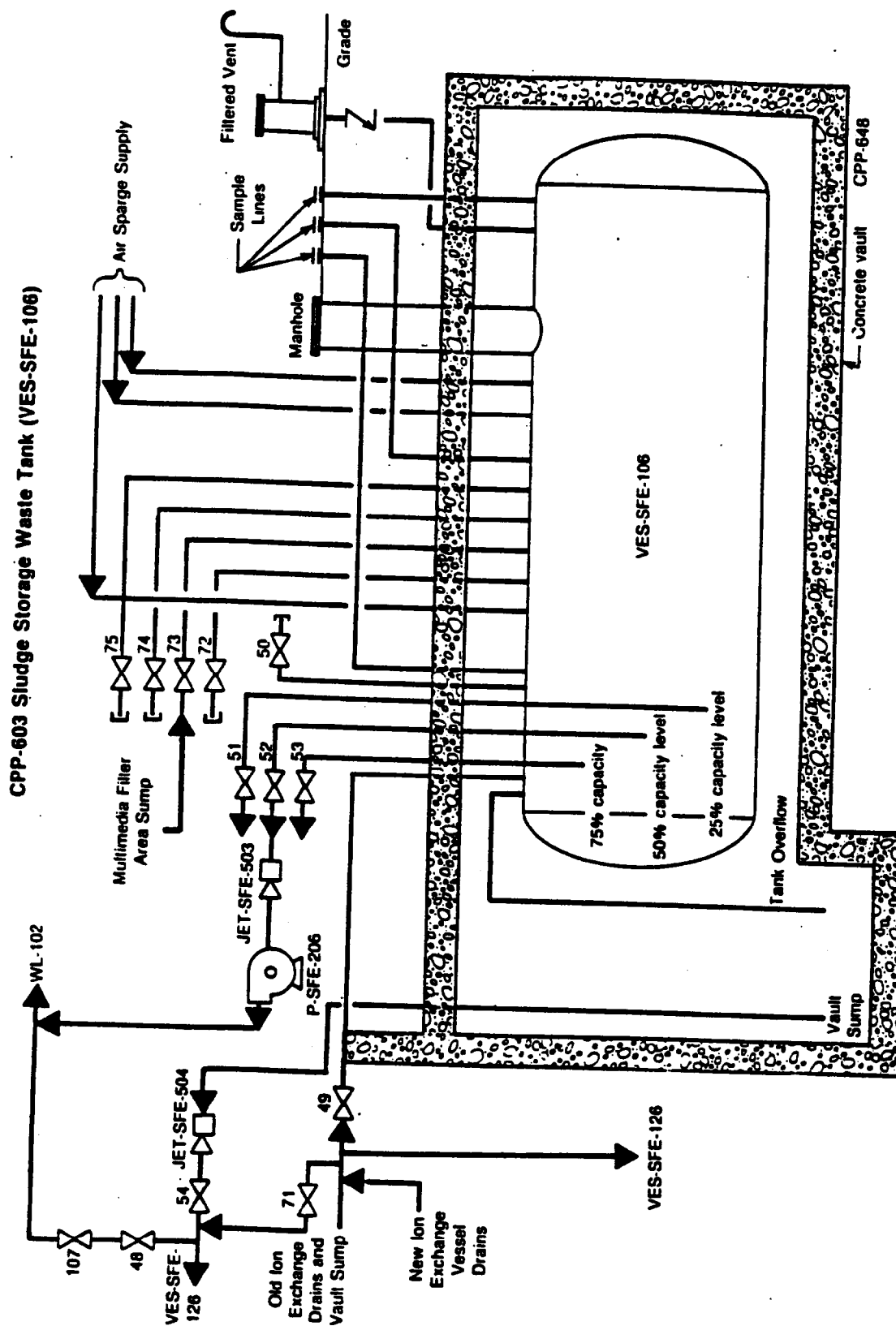
Figure 27. CPP-603 Sludge Storage Waste Tank (VES-SFE-106)

5. Safety Evaluation

A safety evaluation was performed to determine the adequacy of design features and administrative controls for various safety-related aspects of operating the underwater fuel storage facility at CPP-603. The basic areas of safety considered here are: (1) criticality safety, (2) radiological safety, and (3) industrial safety (fire and explosion, and chemical hazards). Sections discussing postulated abnormal occurrences, environmental considerations and natural phenomena are also included.

5.1 CRITICALITY SAFETY

This section includes a discussion of the criticality safety criteria, calculations, safety features and controls, and accident scenarios.

5.1.1 Criticality Safety Criteria

The criticality safety of fuel handling and storage operations at the CPP-603 underwater fuel storage facility is determined by assessing the calculated k-effective values for the fuel configurations (normal and accident cases) against an established set of criticality safety criteria. These criteria, which are contained in DOE and DOE-ID Orders,[6,7] are as follows:

1. A maximum k-effective (k_{eff}) value of 0.95 is allowed for criticality safety parameters developed from calculations. This value must include the effects of credible accidents, of equipment tolerances and the uncertainties of the calculational method.

2. If criticality safety is by mass control, then a system must be limited to 45% of the minimum critical mass (for worst-case geometry) unless double batching is not credible, in which case a higher percentage may be used. The higher value used at the ICPP is usually set at 75%.

3. The double contingency principle is applied to well-shielded areas to determine limits of operation.[8] The term "well-shielded" means that sufficient shielding is provided to personnel outside of the shielding that radiation exposures will not exceed 25 rem whole body under accident conditions. At CPP-603 fuel handling and storage operations are well-shielded by water or by shielded shipping casks/chargers. Double contingency means that sufficient factors must be incorporated (in the design or the analysis) to require at least two unlikely, independent and concurrent changes in process conditions before a criticality accident is possible.

Aside from these criticality safety criteria, it is the policy of the current ICPP contractor to set operating limits such that no single accident results in exceeding a k_{eff} of 0.95 for facilities (such as CPP-603) already existing prior to May 1986.[8] In addition, it is also ICPP policy to implement physical barriers whenever possible, rather than to rely solely on administrative controls to prevent criticality accidents.

5.1.2 Criticality Safety Features and Control Methods

Criticality safety during fuel receiving, handling and storage at the CPP-603 underwater fuel storage facility depends on the following factors:

1. Complete and accurate descriptions of the fuel.

2. Accurate criticality safety evaluations to demonstrate that the proposed storage and handling configurations have an adequate safety margin.

3. Adequate controls to ensure the designated material is received and properly accounted for.

4. Adequate controls to ensure fuel integrity is maintained.

5. Adequate controls to ensure approved administrative safety controls for fuel limits and configuration are not violated.

6. An adequate equipment surveillance and corrosion inspection plan.

7. Operating personnel trained and certified to comply with the applicable administrative controls.

At CPP-603 many of the criticality control limits are developed from calculations based on a generic fuel unit, although specific calculations are done as necessary. Criticality calculations are accomplished on a variety of bases, the default basis using beginning of life (BOL) fissile content with no credit taken for the poisons in the fuel. Occasionally it is necessary to use data at the "most reactive time of life" (MRTL) of the fuel, with some fissile material and burnable poison depletion, as the bases for the calculations. At the ICPP, calculations using an "End of Life" (EOL) basis, a method which takes into account actual fissile material and poison contents in the fuel after burnup depletion, are not permitted.

Administrative and physical controls are imposed as necessary to meet the double contingency criteria for criticality accident prevention as required in the DOE Order.[7] Complete dependence on physical barriers for these contingencies is desirable, but not practicable in this facility due to the large number of manual fuel handling operations performed. Physical barriers to criticality are incorporated into the design of storage equipment and transfer casks, as described below.

Fuel storage in the south basin is accomplished in two types of racks, the RK-SF-901 racks and the RK-SF-900 racks. The RK-SF-901 rack storage array consists of tubes constructed from aluminum pipe. The RK-SF-901 rack design provides at least 8 in. of isolation around the individual rack arrays and over the top of fuel in the rack since the height of the fuel in the rack position is administratively limited.

The stainless steel racks, RK-SF-900, are designed to provide at least an 8-in. edge-to-edge separation between the individual rack positions. There is also a 4-in. separation between the rack edge and the edge of the peripheral rack positions. This design feature results in at least an 8-in. edge-to-edge separation between peripheral rack positions of two adjacent and touching RK-SF-900 racks, and any other rack type where at least a 4-in. edge separation is provided. The rack storage tube is also sufficiently tall that an eight-in. water gap can be administratively required without adversely impacting the use of these racks. The rack design results in a limited degree of interactive

reactivity between rack positions given that the certain fuel parameters are administratively controlled, i.e., single position k_{eff}, fissile mass density and fuel length. The rack storage tubes are equipped with lids, which, when closed, act as barriers between the stored fuel and external fuel in transit.

Criticality safety is enhanced by the design of the basin monorail system. Each track (or rail) is 24 in. from its adjacent parallel track thereby providing physical isolation from the adjacent row of fuels.

Concrete dividers (barriers) on the basin floor and at the water level ensure that fuel does not swing toward adjacent rows. Separation of fuels on each track is maintained at 24 in. center-to-center by the upper bumpers on the fuel storage yokes. The lower bumpers on each yoke provide at least 18 in. center-to-center spacing between adjacent fuels. The lower bumpers provide assurance that a pendulum motion of a yoke would not allow the storage buckets on two similar yokes to come into contact. Even with the lower bumpers in contact, there is at least 8 in. of water separation between fuels on adjacent hangers, provided that the sum of the radii of the fuel regions does not exceed 11 in. If the lower bumpers are not at the same elevation, the dissimilar yokes may be separated with an empty bucket.

Complete dependence on physical barriers to prevent criticality at CPP-603 is not possible. Generally, those physical features that enhance criticality safety at this facility must be accompanied by administrative controls, which either require the use of the feature or limit the scope of its applicability (e.g., fissile material loading limits). Thus, administrative controls are used, where necessary to implement the physical controls. These administrative controls and physical features are presented in the conclusions of this safety evaluation as operational safety requirements (see Section 6.0). These requirements are, as necessary, implemented by Technical Standards and incorporated into the operating procedures.

When a new fuel (i.e., previously unevaluated) is to be received for storage at any ICPP fuel storage facility, requests for safety

evaluations, particularly criticality, are the responsibility of the fuel handling manager in the Production Department. This manager is also responsible for determining in which facility the new incoming fuel will be stored, whether it will be stored underwater or dry, and how it will be configured while it is in storage. This information is transmitted to the criticality safety section, which has the responsibility to perform the primary criticality safety evaluation and to arrange for the necessary independent reviews and calculations.

The criticality safety evaluations envelope the safety of transfer, handling, and storage operations and are based on the fuel information provided by the fuel handling manager. These criticality safety evaluations either confirm the safety of the proposed storage method or location, or modify those proposals, as necessary, to ensure an adequate margin of safety. An evaluation for criticality safety is also required, in addition to appropriate approvals, before initiating a recovery plan to correct abnormal fuel storage configurations (i.e., recovery of fallen buckets).

Specific evaluations have been performed for the fuels in storage. In some cases the evaluation results have been compared with generic fuel model curves by using the appropriate parameters of the individual fuels to determine the reactivity effects of postulated accident configurations. These curves are discussed in the criticality calculations section that follows. The Criticality Safety Section evaluates and defines the following for each fuel type:

(1) Approved storage limits--This consists of the maximum number of fuel elements or components allowed to be stored per specified storage position (e.g., fuel bucket, rack position, or both). The specific storage configuration for each type of fuel, determined from a criticality safety evaluation, must be approved by ICPP contractor management and DOE-ID.

(2) Fuel Handling Unit (FHU)--This is the maximum assemblage of a particular fuel (pins, plates, elements) that may be out of approved storage. Only one FHU may be out of the approved storage position at any one time in each of the three basins, the two transfer stations and the transfer canal.

Each fuel now stored in the CPP-603 underwater facility has an approved storage limit (including combinations of fuel types and configurations if specified) and an approved fuel handling unit. These approved storage and handling limits for the respective fuels in storage are listed in the applicable Technical Standard. The Technical Standard listing is updated, as necessary, to add new fuels, which are enveloped by the safety evaluation presented in this document.

The transfer, handling, and storage limits, were developed to provide sufficient margin so that certain credible accidents, such as bringing two storage buckets side-by-side, or dropping one fuel handling unit on top of a fully-loaded rack will not cause a criticality. Fuel storage and handling limits are derived from safety considerations as opposed to operating efficiency and/or optimization of fuel density. The potential criticality accidents identified in this analysis are discussed in Section 5.1.4.

The structural integrity of the racks is an integral part of critically safe fuel storage. Criticality safety is maintained in part by the rack spacing (for positions) in the "as-built" condition. To preserve the integrity of the rack and to prevent loss of storage geometry, loaded racks must not be lifted or moved. If a rack, which does not contain fuel, is moved or lifted, it must not be carried over other fuel-loaded racks. In general, fuel handling units (or other heavy objects) are not carried over racks unless they are being loaded into a storage position of that particular rack.

5.1.3 Criticality Calculations

Criticality calculations are performed for various fuel configurations, normal and abnormal, at CPP-603 to determine the margin of safety either inherent in the system or imposed by the operational safety requirements. Criticality calculations also include the sensitivity of k_{eff} to equipment design and operating parameters. Criticality calculations also identify fuel configurations that pose a potential criticality hazard.

A summary of the criticality safety evaluations for the CPP-603 underwater facility is provided in Table V. The calculations presented in this table are generally intended as scoping calculations that define the criticality safety envelope of the facility. Several of the calculations are specific examples included as basis material for the development of the criticality accident scenarios. These calculations are discussed in the following subsections (where the section number matches that of case number in Table V).

5.1.3.1 <u>Case 1</u>. An ATR-based study[9,10] was performed to determine the reactivity effects of various parameters on the RK-SF-901 rack array. The parameters studied were the effect of cross-sectional area and linear loading. Uranium loadings were based on two U-235 values, 1100 g and 2000 g total. The ATR fuel element was modeled as a rectangular solid 63 in. in length with the actual water volume fraction of the fuel included in the model. The effect of centered and off-centered fuel units was also considered. As indicated in the results (Table V), the off-centered fuel unit array is more reactive, reactivity increases with increased linear loading, or with increased fuel cross-sectional area. The actual ATR fuel does not exceed 1100 g U-235 per element.

5.1.3.2 <u>Case 2</u>. The reactivity of the RK-SF-901 rack array was also evaluated with generic fuel units, 3 x 3 x 63-in. cuboids. In this calculation,[10] the uranium loadings assumed were 500 and 600 g U-235, with no U-238. The k_{eff} (0.827 $\pm$ .009) of the rack for 500 g U-235/ft and 0.60 water volume fraction, off-centered, is comparable to that for the 500 g U-235/ft result (i.e., 0.796 $\pm$ 0.008) reported for a fuel cross-section equivalent to that for an ATR fuel element. Based on the generic fuel calculations, storage of fuel units with a loading of 600 g U-235/ft and a water volume fraction of 1.00 in this rack is not safe.

Table V. Summary of CPP-603 Criticality Calculations

Case	Assumptions and Bases	Calculated Results	CSE Reference
South Basin Storage Racks			
1. Determine the k-eff for an RK-SF-901 rack fully-loaded with ATR fuel elements.	1. ATR fuel cross-section converted to equivalent rectangle in calculations. Effect of increasing ATR cross-section by 1.82 and 2.18 (largest size that can be placed in fuel storage tube) considered.	(1.00) ATR, 275 g U-235/ft k-eff 0.673 ± 0.008 centered 0.708 ± 0.006 off-centered (1.00) ATR, 500 g U-235/ft k-eff 0.732 ± 0.008 centered 0.796 ± 0.008 off-centered	WGM-8-80 (9) WGM-18-80 (10)
	2. ATR length modeled as 63 inches, actual WVF (0.60) used in calculations.	(1.82) AIR 500 g U-235/ft k-eff 0.918 ± 0.008 centered 0.942 ± 0.010 off-centered	
	3. Fuel plates (Al and U-235) homogenized with water and discrete side plates of Al used in fuel unit model.	(1.82) ATR, 909 g U-235/ft k-eff 0.985 ± 0.010 centered (2.18) ATR, 600 g U-235/ft k-eff 1.038 ± 0.008 centered	
	4. Uranium loadings in model based on 1100 and 2000 g U-235 as U(93.2) per assembly.		
	5. Effects on fuel units centered and off-centered in fuel storage tubes considered in calculations.	(Note: the high linear loadings in the above arise from the combination of expanded fuel cross-section and/or g U-235/ft values used in the CSE modeling)	
2. Determine the k-eff for an RK-SK-901 rack fully-loaded with generic fuel elements.	1. Generic fuel unit modeled as a 3.0 x 3.0 x 63-inch cuboid.	No Al, WVF 1.00, 500 g U-235/ft k-eff 0.855 ± 0.009 centered 0.936 ± 0.009 off-centered	WGM-18-80 (10)
	2. Fuel unit loading of 500 and 600 g U-235/ft considered, U(100).	No Al, WVF 1.00, 600 g U-235/ft k-eff 0.884 ± 0.009 centered 0.956 ± 0.009 off-centered	
	3. Uranium and water homogenized, two different compositions used; i.e., Al included and WVF 0.60 or Al neglected and WVF approximately 1.00.	Al, WVF 0.60, 500 g U-235/ft k-eff 0.770 ± 0.009 centered 0.827 ± 0.009 off-centered	
	4. No discrete Al side plates considered in model.	Al, WVF 0.60, 600 g U-235/ft k-eff 0.788 ± 0.007 centered 0.858 ± 0.009 off-centered	

Table V. (Contd.) Summary of CPP-603 Criticality Calculations

Case	Assumptions and Bases	Calculated Results	CSE Reference
3. Determine k-eff of fully-loaded RK-SF-901 rack based on special off-centering study.	1. Generic fuel unit modeled as a 3.0 x 3.0 x 63-inch cuboid. 2. Fuel unit loading of 500 and 600 g U-235/ft considered U(100). 3. Fuel unit modeled as homogenized U-235 and water (WF > 0.6), with no structural material included. 4. Off-centered fuel configuration modeled as groups of seven fuel storage tubes with fuel units at minimum separation. Groups either close-packed (staggered) or lined up in a row.	Staggered groups g U-235/ft k-eff 500 0.913 ± 0.005 600 0.944 ± 0.005 Row line-up of groups g U-235/ft k-eff 500 0.924 ± .005 600 0.939 ± .005	JAE-24-80 (11)
4. Determine the k-eff for an RK-SF-901 rack fully-loaded with larger generic fuel elements.	1. Generic fuel unit modeled as a 3.3 x 3.3 x 55-inch cuboid. 2. Fuel composition of fuel units modeled as a homogeneous mixture of U-235, water and Al and no U-238. 3. Fuel unit centered in the fuel storage tube. 4. Parametric calculations done with U-235 linear densities of 200, 400, and 600 g/ft, each with water volume fractions of 0.6, 0.8 and 1.0 (balance Al).	WF 1.0 g U-235/ft 200, k-eff 0.785 ± 0.005 g U-235/ft 400, k-eff 0.903 ± 0.005 g U-235/ft 600, k-eff 0.941 ± 0.005 WF 0.8 g U-235/ft 200, k-eff 0.734 ± 0.005 g U-235/ft 400, k-eff 0.838 ± 0.005 g U-235/ft 600, k-eff 0.886 ± 0.005 WF 0.6 g U-235/ft 200, k-eff 0.686 ± 0.005 g U-235/ft 400, k-eff 0.778 ± 0.006 g U-235/ft 600, k-eff 0.830 ± 0.004	RE-P-82-081 (E&G) Idaho) (12)

Case	Assumptions and Bases	Calculated Results				CSE Reference
5. Determine the k-eff for an RK-SF-901 rack loaded in 74 positions with TORY IIA fuel cans.	1. TORY IIA fuel in close-packed array of 74 positions in rack.		BeO g	Water g	Array k-eff	SD-T-82-010 (EG&G Idaho) (13)
			10,000	970.9	0.766 ± 0.007	
	2. U-235 per can 602 g.		2,000	3722.8	0.890 ± 0.007	Rew-34-81 (14)
	3. TORY IIA can in bucket and two buckets per rack position in an end-to-end configuration.	10.4 % UO2 k-eff		0.819 ± 0.005		
	4. Fuel material homogenized over volume of the can, U-235 and BeO, with water filling the balance of the volume.					
6. Determine maximum single position k-eff value such that array k-eff of an RK-SF-900 rack does not exceed 0.95.	1. Fuel units modeled as homogenized U-235, water and structural material, Zr, Al or stainless steel.	Single position k-eff of 0.916, where stored FMU linear loading does not exceed 5.0 kg U-235/ft results in an overall rack array k-eff value that does not exceed 0.95. Fuel water volume fraction is not limited to a minimum at this value. Rack k_eff diminishes as the water volume fraction in the fuel decreases. The 0.916 single position value arises from the array interaction, 0.032 and the interaction due to the fuel on top of the rack, 0.002.				VLP-28-85 (15) ERA-NE-028 (59)
	2. Infinite array of rack positions at design spacing.					
	3. Fuel storage tube modeled as infinite in height.					
	4. Full-sized (i.e., filling the rack position) FMUs and off-centered considered.					
	5. Effect of fuel unit on top of rack array modeled as slab of homogenized U-235 and water, water gap thickness between top of fuel and slab varied.					

Case		Assumptions and Bases	Calculated Results	CSE Reference
7.	Determine the maximum single position k-eff for an RK-SF-900 rack array with a single fuel unit closer than 8 inches to the stored fuel; such that the rack array k-eff does not exceed 0.95.	1. Array model of four units, one in each of the corner positions of three racks in a 2 x 2 -1 (i.e., an "L-shaped array") with the fourth fuel unit placed against all three racks in the inside corner formed by the array of racks.	0.25 water volume fraction and 2.5 kg U-235/ft, single position k-eff limited to 0.86 to account for effects of close fuel unit on the array reactivity.	IEF-05-82 (16)
		2. Structural material of square rack storage tube included in rack model.	0.30 water volume fraction and 5.0 kg U-235/ft, single position k-eff limited to 0.88 to account for effects of close fuel unit on the array reactivity.	IEF-04-81 (17)
		3. Various fuel water volume fractions, balance Zr and linear U-235 loadings considered in calculations.		
		4. Fuel fills entire rack position.		
North and Middle Basin Storage				
8.	Determine the k-eff for various fuel cross-section, WVF and mass loadings (g U-235/ft) for storage of fuel in buckets (as on the monorail system).	1. Two fuel loaded storage buckets are in contact.	The calculated results for these parameters are shown as plots in	JAE-15-75 (18) JAE-3-76 (19)
		2. Two bucket system modeled as a single cylinder with homogenized uranium and water.	Figure 30 for 800 g U-235/ft Figure 31 for 1000 g U-235/ft Figure 32 for 1400 g U-235/ft.	
		3. Water volume fraction varied from 0.25 to 1.0, with Zr as balance.		
		4. Total loading (sum of two buckets) used in calculations were 800, 1000 and 1400 g U-235/ft.		

Case		Assumptions and Bases	Calculated Results	CSE Reference
North and Middle Basin Storage (Contd.)				
9.	Determine the k-eff for an array of eight fuel units (four each in two buckets) with various mass loadings (g U-235/ft) and water volume fractions.	1. Two fuel-loaded storage buckets are in contact.	**2 x 4 array, 0.75 WVF** 100 g U-235/ft, k-eff 0.968 ± 0.007 150 g U-235/ft, k-eff 1.046 ± 0.011	JAE-15-75 (18)
		2. Fuel units modeled as eight individual pieces in a 2 x 4 or 1-3-3-1 array (see Figure 33) at optimum spacing.	**2 x 4 array, 0.50 WVF** 100 g U-235/ft, k-eff 0.894 ± 0.008 150 g U-235/ft, k-eff 0.992 ± 0.012	Fiel-21-76 (20) (Aerojet Nuclear)
		3. Fuel meat section of each fuel piece modeled as 3.0 x 3.0 x 55-inch cuboids.	**1-3-3-1 array, 0.75 WVF** 100 g U-235/ft, k-eff 0.978 ± .014 150 g U-235/ft, k-eff 1.094	
		4. Fuel modeled as a homogeneous uranium-water-zirconium mixture.	**1-3-3-1 array, 0.50 WVF** 100 g U-235/ft, k-eff 0.927 ± 0.016 130 g U-235/ft, k-eff 0.962 ± 0.016	
Fuel Element Cutting Facility (FECF)				
10.	Determine the criticality safety of the two canned Peachbottom fuel elements in the FECF.	1. Two canned Peachbottom fuel elements (C-0505 and E-0505) are located in the FECF, and are estimated to contain 582 g U-235 total.	The 582 g U-235 mass in the FECF is 71% of the assumed critical mass basis and the safety factor is 1.4.	VLP-17-84 (22)
		2. Criticality safety based minimum critical mass of 820 g U-235 for a uniform U-235 solution with full water reflection.		
Auxiliary Systems				
11.	Determine the minimum critical concentration of U-235 in basin floor sludge stored in VES-SFE-106.	1. VES-SFE-106 completely filled with sludge and has 1-inch walls.	k-eff = 1.00 at 6.1 g U-235/L	WGM-15-73 (23)
		2. 12-inch concrete reflection from vault, one feet from the tank (VES-SFE-106) at closest point.		
		3. Sludge modeled as iron-free and with 5% water.		

Case		Assumptions and Bases	Calculated Results	CSE Reference
Specific Fuel Calculations				
12.		Determine the k-eff for six ATR fuel elements.		
	1.	Each fuel element contains 1100 g U-235 with no boron.	2 x 3 array, k-eff is 0.97 ± 0.02 cylindrical array, k-eff is 1.004 ± 0.015	FMc-504-71, (TRA Fuel Handling Study by Briscoe and Eggert, Aerojet) (24)
	2.	Full water reflection of fuel.		
	3.	Homogenized fuel region, some calculations with discrete Al side plates.	In a separate calculation, with 4 g boron per fuel element, the 2 x 3 array k-eff was 0.90 ± 0.02.	JKF-17-71 (25)
	4.	Six units modeled as a 2 x 3 array and cylindrical array with five elements around a center element.		
	5.	Calculations made at 0.8 inches of spacing between fuel elements.		
13.		Determine minimum critical number of EBR-II fuel element containers.		
	1.	U(67), uranium stainless steel clad and sodium homogenized with voids filled with water in calculation.	Triangular pitch array of 12 containers, k-eff is 0.98 ± 0.008, so 13 is the estimated minimum critical number.	IEF-5-77 (26)
	2.	Center stem in container modeled as full length.	Square pitch array of 12 containers, k-eff is 0.958 ± 0.008; and for 16 containers k-eff is 1.037 ± 0.008.	RE-N-77-026 (27) (EG&G Idaho)
	3.	Fuel element containers in two types of water-flooded arrays, i.e.,	Triangular pitch array of 12 containers, k-eff increases to 1.036.	
		o triangular pitch with center-to-center spacing of 7 cm between 13 containers, or	Square pitch array of 12 containers, k-eff increases to 0.994; for 16 containers k-eff increases to 1.114.	
		o square pitch array of 16 containers in a 4 x 4 array with 1.0 cm spacing between containers, 12 containers in a 3 x 4 array also considered.		
	4.	Calculation repeated, modeling the center stem in the container at the actual length, which is less than the container full-length.		VLP-29-85 (28)

Case		Assumptions and Bases	Calculated Results	CSE Reference
Special Studies				
14. Determine reactivity effect of pool draining accident in the south basin.	1.	Complete draining of the pool, dry fuel and actual array of racks (as of CSE date).	k-eff 0.22	Fast-01-88 (29)
	2.	Retention of water in canned fuel EBR-II (1988 inventory values), partial/full draining of pool.	k-eff <0.7	Fast-01-88 (29)
	3.	TORY-IIA (see Case 8), close-packed in RK-SF-901 rack, wet fuel region and wet buckets, in a dry or partially drained basin.	k-eff >0.95.	Fast-01-88 (29)
	4.	TORY IIA fuel rearranged in rack to distribute empty spaces into fuel array, with		
		- checkerboard distribution, or	k-eff <0.8	Fast-01-88 (29)
		- zone of empty positions dividing array into two zones.	k-eff 0.9	Fast-01-88 (29)
	5.	60 x 30 array of EBR-II loaded RK-SK-900 rack positions, tight concrete reflector on bottom, 21 feet high on sides; flooded fuel in a dry basin.	k-eff 0.590 ± 0.005	NRRT-N-88-029 (30)
	6.	60 x 30 array of generic fuel-loaded RK-SF-900 rack positions (single position k-eff 0.88, and WVF 0.50), tight concrete reflector on bottom, 21 feet high on sides;		
		flooded fuel, dry basin fuel WVF 0.2, dry basin fuel WVF 0.1, dry basin fuel dry, dry basin	k-eff 1.243 ± 0.004 k-eff 1.063 ± 0.004 k-eff 1.925 ± 0.004 k-eff 0.563 ± 0.004	NRRT-N-88-029(30)

Case	Assumptions and Bases	Calculated Results	CSE Reference
Special Studies			
15. Determine reactivity effect of pool draining accident in the north and middle basins.	1. Generic fuel unit modeled in each storage position, containing 4.875 kg U-235, cuboid geometry 17.1 cm by 21.5 cm, 125 cm long.		Fast-08-88 (31)
	2. Intact monorail system with proper location of fuel in the storage positions;		
	2-foot center-to-center spacing dry fuel in dry basin wet fuel in dry basin	Array k-eff 0.18 0.64	
	18-inch center-to-center spacing dry fuel; in dry basin wet fuel in dry basin	Array k-eff 0.23 0.72	
	(Note: "wet fuel" defined as "water-logged" fuel in the CSE, WF of the fuel model is 0.3).		

5.1.3.3 <u>Case 3</u>. A special off-centering study[11] was done for the RK-SF-901 racks to determine maximum k_{eff} values for off-centered fuel in the storage positions. Again the fuel units were modeled as 3.0 x 3.0 x 63-in. cuboids. Only 500 and 600 g U-235/ft loadings were considered, with no U-238. The fuel unit was modeled as homogenized U-235 and water, with no structural material included in the model. The array was modeled as groups of seven fuel units off-centered to decrease the edge-to-edge separation of the fuel units in the groups. Two group arrangements were modeled, with the groups in a straight line (touching at only one point) or close-packed in a staggered line-up (i.e., triangular pitch). Due to the fact the computer code bias may be slightly non-conservative, less than 1.0%, it was concluded in this evaluation[11] that the use of the rack should be limited to a 500 g U-235/ft loading so that the rack array k_{eff} does not exceed 0.95.

5.1.3.4 <u>Case 4</u>. An additional set of calculations were done to determine the reactivity of fuels in an RK-SF-901 rack. In this evaluation,[12] larger generic fuel units, 3.3 x 3.3 x 55-in. cuboids, were modeled. The fuel was modeled as a homogeneous mixture of U-235, water and aluminum with no U-238. The fuel units were centered in the storage tubes. Parametric calculations were performed for 200, 400 and 600 g U-235/ft, and at water volume fractions of 1.0, 0.8 and 0.6 for each loading. In this case, a rack array of 600 g U-235/ft units with a WVF fraction of 1.00 has a k_{eff} of 0.941 ± 0.005. This result is slightly less than 0.95 and the rack is considered safely subcritical if loaded with the generic fuel unit modeled in this calculation.

This case compares with the same calculation done in Case 2 above, where the k_{eff} was 0.956 ± 0.009, and is in excess of 0.95. The slight increase in k_{eff} (in Case 2 as compared to Case 4) is possibly attributable to modeling fuel units with a 63-in. height in Case 2 and fuel units with a 55-in. height in Case 4. The increased fuel height appears to have had a greater effect on reactivity than the increased larger fuel cross-section (3.3 x 3.3-in.).

5.1.3.5 <u>Case 5</u>. The safety of storage of TORY-IIA fuel in the RK-SF-901 racks was considered in two separate evaluations.[13,14] The fuel, a $BeO-UO_2$ mixture in aluminum canisters, had been stored in the TORY-IIA rack since 1962. The original canisters were placed in aluminum buckets and moved to an RK-SF-901 rack in 1983, two buckets stacked in each storage position. The maximum k_{eff} value calculated for the rack, with 74 positions of TORY-IIA fuel in a close packed array, was approximately 0.90. The effects of interaction of this fuel array with another type of fuel in the rack was not determined. Consequently, this rack is dedicated to TORY-IIA fuel storage and intermixing of other fuel types in the rack is not permitted.

5.1.3.6 <u>Case 6</u>. Calculations were performed to determine the fuel characteristics for single fuel units in the RK-SF-900 racks such that the overall rack array k_{eff} does not exceed 0.95. These calculations[15,59] were performed for the use of this rack design at the FAST Fuel Storage Area (FSA, CPP-666), and can be applied to the RK-SF-900 racks at CPP-603. The fuel units were modeled as homogenized U-235, water and structural material (aluminum, zirconium or stainless steel). The fuel storage tubes (and fuel unit) were modeled as infinite in height, and an infinite array of positions (racks) at the design spacing were modeled.

Criticality safety evaluations have been performed for the RK-SF-900 racks to determine the water volume fraction requirements. The calculation results show that, given the other existing controls, the k_{eff} of a rack array will decrease with a decrease in water volume fraction. Therefore, a water volume fraction control is not required, which is consistent with the controls in the CPP-666 FSA.

In addition, the effect of a dropped fuel unit on the array reactivity was modeled as a slab of fuel over the array, at various heights above the array. The single position k_{eff} of 0.916 results in a array k_{eff} that does not exceed 0.95 and accounts for the effect of fuel placed on top of the rack. The fuel unit must also be limited to 5.0 kg U-235/ft. The total interactive reactivity results from a 0.032 array interaction and a 0.002 interaction due to fuel on top of the

rack, with a 6-in. water gap over the stored fuel. Therefore a restriction on the height of fuel in the rack position is necessary.

Storage of EBR-II fuel containers in eight-container rack inserts with two rack inserts placed end-to-end in a storage port, meets the criteria and requirements for storage in RK-SF-900 racks. This storage configuration is currently approved for EBR-II fuel containers at CPP-666. Details of the criticality calculations and the safety analysis are reported in PSD 5.6, Volume III, Addendum B.

5.1.3.7 <u>Case 7</u>. Studies of the RK-SF-900 rack[16,17] also developed single position criteria for this rack. These calculations yielded lower permissible single position k_{eff} values (as compared to Case 6 above), due to consideration of an array with less than the 8-in. edge-to-edge separation between positions provided by the rack design. In this case the racks were modeled in a 2 x 2 - 1 array, an "L-shaped" array with fuel in each of the three rack corner positions and a fuel unit placed against the racks in the inside corner of the "L-shape." One of these studies[17] concluded that a single position k_{eff} of 0.88, with a fuel loading limit of 5.0 kg U-235/ft and a minimum water volume fraction of 0.30 was critically safe with respect to the overall fuel storage array. This limit on single-position k_{eff} (0.88) also provides sufficient margin such that a single accident of a fuel unit on top of the storage rack will not result in an array k_{eff} greater than 0.95. Criticality calculations supporting the RK-SF-900 racks containing the most reactive CPP-603 fuel and a most reactive fuel element up against the rack were performed.[60,61] These calculations determined the basis for the 0.88 single position k_{eff}, with a fuel loading limit of 5.0 kg U-235/ft, to be conservative without a control on water volume fraction. This assumes only fuels currently in storage at CPP-603. Any new fuel brought into CPP-603 or repackaged CPP-603 fuel must be evaluated against these criteria prior to storage in an RK-SF-900 rack.

Due to the demonstrated sensitivity of position spacing on the array reactivity for this rack, this rack is administratively separated from other types of racks such that the peripheral rack positions of this rack are separated from rack positions in other racks by at least 8 inches.

At the present time, this spacing is provided by design since only two types of racks, RK-SF-900 and RK-SF-901, are used for fuel storage in the south basin. In addition, fuel in the rack is isolated at the top by requiring an 8-in. water gap over the fuel. The interaction between a dropped fuel and stored fuel is zero at this separation as shown by the reference cited in Case 6.

5.1.3.8 Case 8. A parametric study[18,19] was done to determine the fuel characteristics for safe storage in buckets on the monorail system in the north and middle basins. The fuel cross-section, water volume fraction and U-235 loadings were varied to determine the effects of these parameters. Two separate fuel storage buckets were modeled as a single cylinder of homogenized uranium and water (e.g., buckets in contact). The fuel water volume fraction was varied from 0.25 to 1.00, with Zr as the balance of the fuel volume. The total fuel loading of the two-bucket system used in the calculations was 800, 1000 and 1400 g U-235/ft.

The results of these calculations are shown in Figures 28, 29, and 30 for 800, 1000 and 1400 g U-235/ft loadings. Two curves are provided for each water volume fraction in these figures, one for void and one for Zr as the balance of the fuel volume fraction. Substitution of void by zirconium in systems having water volume fractions of 0.25, 0.50 and 0.75 increases the reactivity above that for void only, over a range of fuel radii. Substitution of aluminum for void has less effect than zirconium, although the reactivity is still increased. Substitution of stainless steel for the voids decreases the reactivity below that for void due to the poisoning effect of the steel.
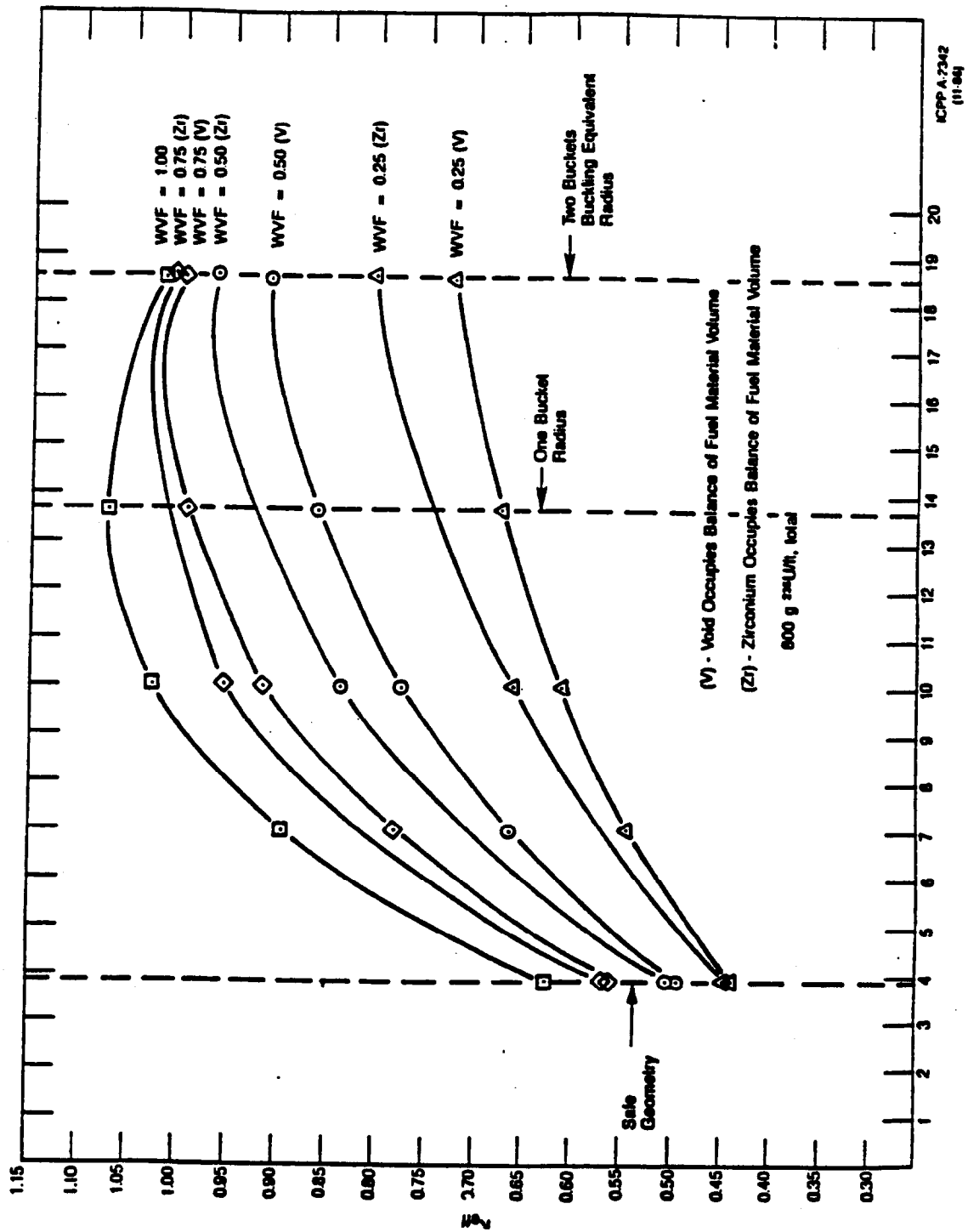
Figure 28. K_{eff} vs. Effective Fuel Radius for Fuel in Buckets
800 g U-235/ft
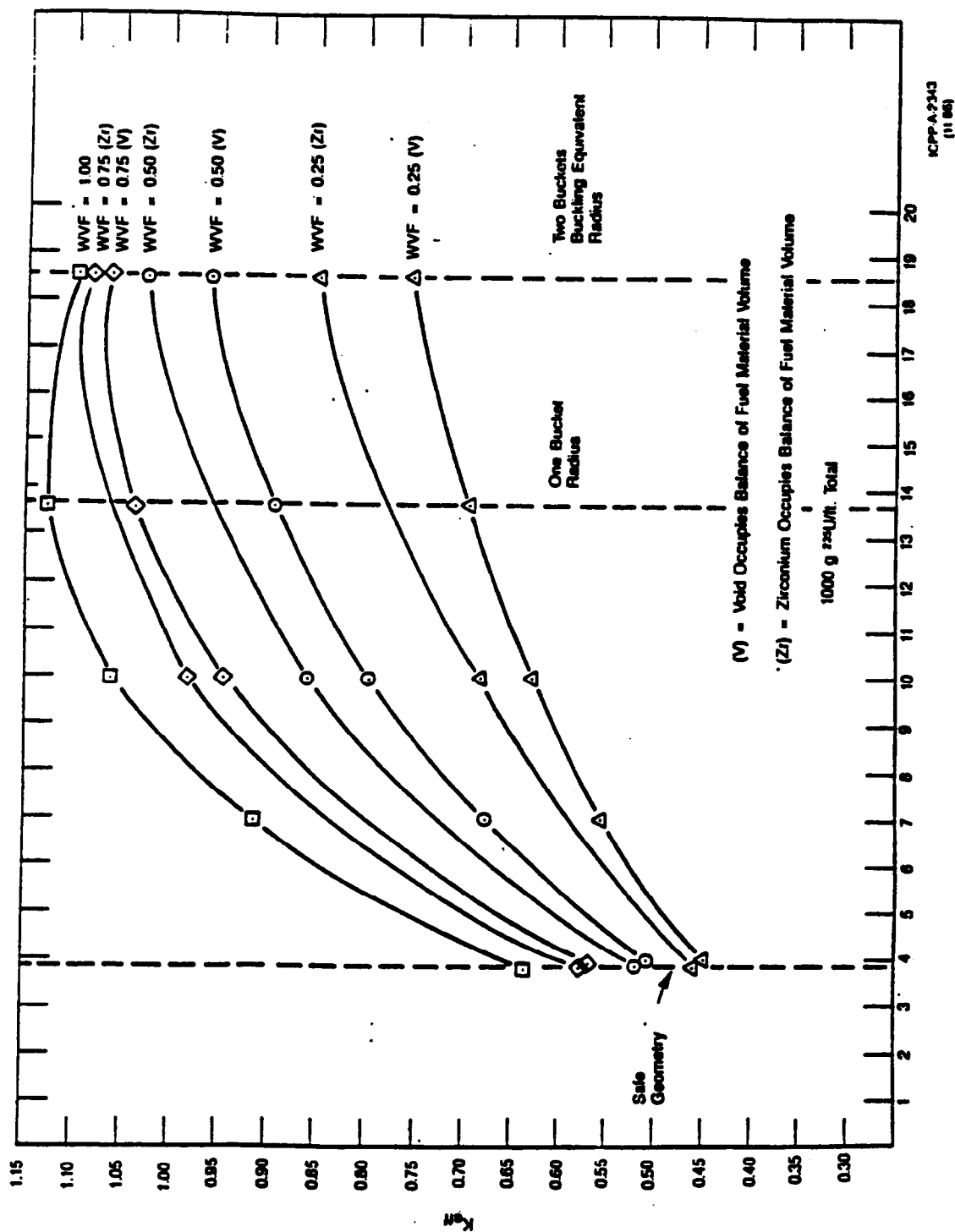
Figure 29. K_{eff} vs. Effective Fuel Radius for Fuel in Buckets 1000 g U-235/ft
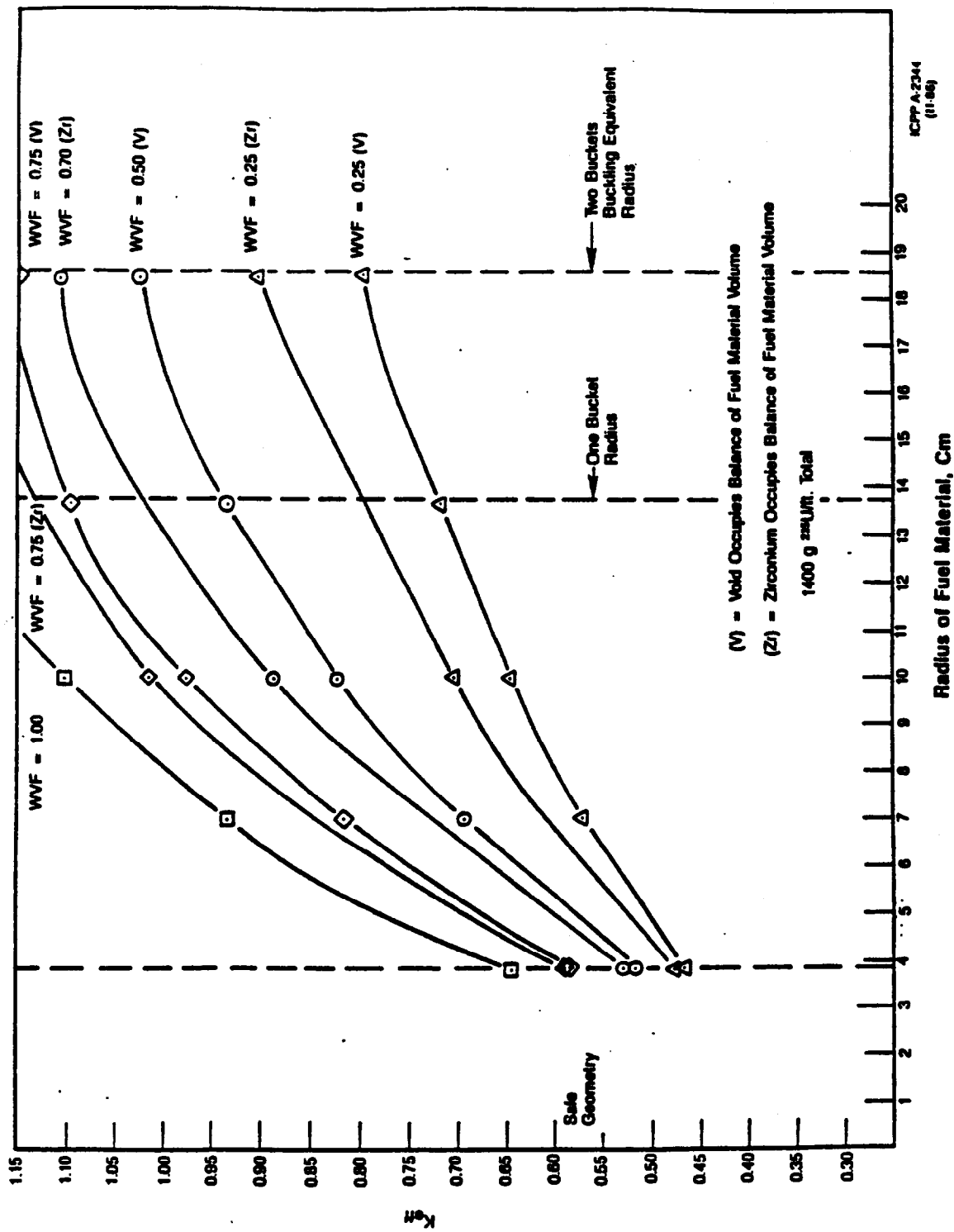
Figure 30. K_{eff} vs. Effective Fuel Radius for Fuel in Buckets
1400 g U-235/ft

5.1.3.9 __Case 9__. The two-bucket system considered in Case 8 above was also evaluated with discrete fuel pieces at optimum spacing. In these calculations, the fuel pieces were modeled as eight individual pieces (four per bucket) in a 2 x 4 or a "1-3-3-1" array as shown in Figure 31. Fuel units were modeled as 3.0 x 3.0 x 55-in. cuboids of a homogeneous uranium, water and zirconium mixture. These results indicate that bucket storage is critically safe (less than k_{eff} of 0.95) under the abnormal condition of two buckets coming together, if the fuel units are limited to 100 g of U-235/ft (bucket total of 400 g of U-235/ft) and a maximum water volume fraction of 0.50.

The calculations discussed here and in Case 8, above, define the safety parameters for fuel storage on the monorail assuming that two adjacent fuels or buckets come together. An alternate approach for bucket storage is to determine the minimum critical mass, i.e., number of fuel pieces, for a specific fuel component. The bucket storage limit is 45% of this calculated value. In the case of storage of larger single units on the monorail system (generally without a bucket), the k_{eff} of two such units optimally spaced is determined. An empty hanger is required between two units if the k_{eff} exceeds 0.95 for the two at optimum spacing.

5.1.3.10 __Case 10__. The Fort Belvoir rack is located in the Fuel Element Cutting Facility (FECF) and was originally used for storage of canned EBR-I Mark IV fuel. This fuel has been removed from the ICPP and no further use has been identified for this rack. At the present time (1996) there are two fuel items in the FECF, of which one is in the rack. These two fuel items, Peachbottom fuel pieces identified as C-0505 and E-0505, are estimated to contain 582 g U-235 total. On a mass basis, it was concluded that storage of these fuel items in the FECF is safe.[21] The uranium mass in the FECF is 71% of a minimum critical mass of 820 g U-235 (for a uniform aqueous uranium solution with full water reflection).

5.1.3.11 __Case 11__. The criticality safety aspects of handling uranium-containing sludge from the CPP-603 basin were studied with respect to the waste tank VES-SFE-106.[22] A three-dimensional mockup of
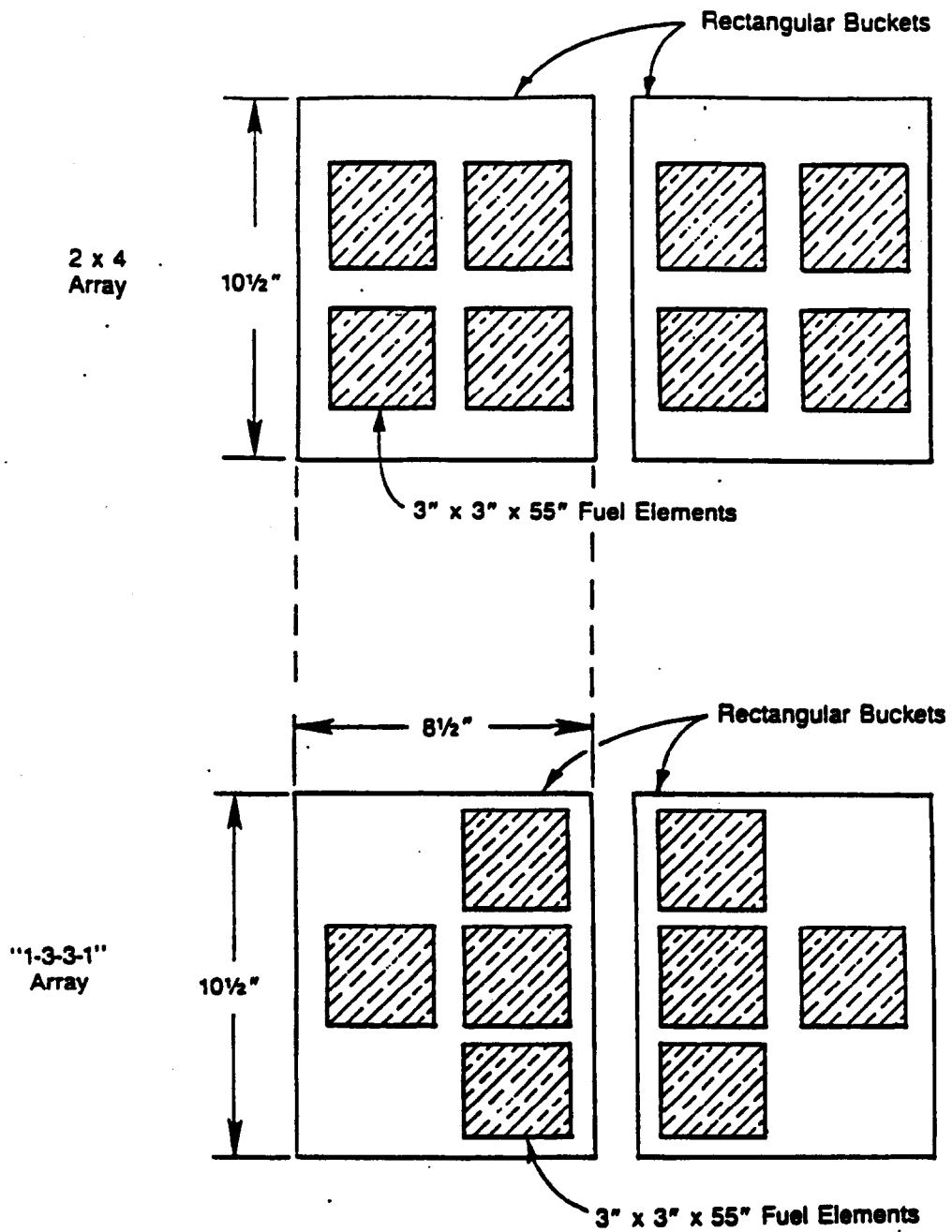
Figure 31. Array Shapes for Eight Fuel Units

the tank in the concrete vault was used in the model. The sludge composition used in the calculations was iron-free and with 5% water. The critical concentration of uranium in the sludge was 6.1 g U-235/L with the k_{eff} dropping to 0.80 for 5.0 g U-235/L. The results of this calculation are not reflected in any administrative controls because most of the sludge was removed from the basin water by a subcontractor in the late 1970's.

5.1.3.12 <u>Case 12</u>. Specific fuel component calculations were done to estimate minimum critical numbers of pieces. In this case, the calculations[23] were done to establish this parameter for ATR fuel assemblies. The ATR was modeled as 1100 g U-235 per fuel unit, with no boron. The fuel region was homogenized and some runs included Al side plates. Six fuel units were modeled in two types of arrays, a 2 x 3 array and a cylindrical array of five units around the sixth. The spacing between fuel units was 0.8 in.. The cylindrical array is critical, with a k_{eff} of 1.004 $\pm$ 0.015. The 2 x 3 array is in excess of 0.95, with a k_{eff} of 0.97 $\pm$ 0.02. An earlier calculation[24] of the 2 x 3 array with 4 g boron per unit indicated a k_{eff} of 0.90 $\pm$ 0.02.

5.1.3.13 <u>Case 13</u>. The minimum critical number of EBR-II containers has been determined in two calculations.[25,26] In both studies, the uranium was assumed to be 67% enriched and the fuel in the container was modeled as homogenized uranium, stainless steel clad, and sodium with water filling the voids. In one calculation, the k_{eff} of 12 containers in a triangular pitch array with 7 cm spacing between containers is 0.98 $\pm$ 0.008. In that case,[25] it was concluded that 13 containers was the minimum critical number. In the second study,[26] square pitch arrays, 1.0-cm spacing between containers, of 12 (3 x 4) and 16 (4 x 4) containers were evaluated. The 12-container array k_{eff} was 0.958 $\pm$ 0.008, and the 16-container array k_{eff} was 1.037 $\pm$ 0.008. In this study, the minimum critical number was estimated at 13 or 14 containers.

As identified in a later study,[27] both of these criticality evaluations modeled the inner tube of the containers as full-length, rather than the actual length, a nonconservative approach. The longer inner tube model results in underestimating k_{eff} values due to increased

neutron poisoning by the stainless steel along the length. The minimum critical number of EBR-II containers was accordingly decreased in the later study to account for this nonconservative effect. The actual k_{eff} of the 12 containers in the triangular array is about 1.036, decreasing the minimum critical number to 11 containers. In the square pitch array study, the 12-container array k_{eff} was increased to 0.994 and that for the 16-container array to 1.114. The minimum critical number for the square pitch array is 12 containers, rather than the 13 or 14 calculated previously.[27]

In conclusion, the smallest minimum critical number of EBR-II containers is 11.

5.1.3.14 Case 14. The effect of a pool drainage accident on the reactivity of the south basin fuel was considered in two studies.[28,29] In one study the actual basin fuel storage array (at the time of the study) was modeled with actual fuel inventory loadings.[28] Various combinations, wet and dry fuel in completely or partially drained arrays were evaluated. The k_{eff} of the south basin is very low, 0.22, if the pool drains completely and the fuel is dry. The k_{eff} of the EBR-II fuel array, with water retention in the fuel container, and partial draining of the pool, does not exceed 0.70. The TORY-IIA fuel, modeled in the RK-SF-901 racks (see Case 8), had a calculated array k_{eff} in excess of 0.95, with wet fuel and buckets in a dry or partially drained pool.[28]

Further calculations were done to determine rearrangements of the TORY-IIA array in the RK-SF-901 rack that would have a k_{eff} below 0.95 for the various combinations of wet/dry fuel and pool considered. If the array is split into two sections with the empty rack positions between each half of the array, the k_{eff} is a maximum of 0.90. If the empty positions are distributed into the fuel array in a checkerboard fashion, the k_{eff} is less than 0.80.[28] This rearrangement, checkerboard array, was completed during August 1988.

In the other study of the south basin pool draining accident,[29] a 60 x 30 position array of the stainless steel RK-SF-900 racks, was modeled in the pool with a tight-fitting concrete reflector on the bottom

of the array and 21 feet high on the sides. The maximum calculated k_{eff} for the array filled with EBR-II fuel (16 containers per rack position divided into two tiers of eight containers) was 0.60, assuming flooded fuel region (center tube of container dry) and a dry pool.[29]

The effect of pool draining on a RK-SF-900 rack array (60 x 30), reflected as above, containing a generic fuel was also evaluated.[29] In this case a generic fuel unit was modeled such that the single position k_{eff} was 0.88, and the fuel water volume fraction was 0.5. The k_{eff} of such an array, assuming flooded fuel and a dry basin is very high, 1.25. If the water volume fraction of the fuel decreases to 0.1, the k_{eff} of such an array, in a dry basin, is less than 0.95.[29] Water drainage from uncanned fuel units during a basin drainage accident such that the water held in the fuel is less than 20% of the water content when fully-flooded is sufficient for a critically safe fuel array.

5.1.3.15 <u>Case 15</u>. The effects of a pool draining accident on the fuel storage array in the north and middle basins were also evaluated.[30] A generic fuel unit was modeled for each storage position which contained 4.875 kg U-235, 0.3 void volume. The fuel unit was modeled as a cuboid with a cross-section of 17.1 cm by 21.5 cm and 125 cm in length. The monorail system was assumed to be intact and the fuel was assumed to be properly located in the storage position (bucket). At the normal two-foot center-to-center spacing between fuel units, the array k_{eff} for dry fuel in a dry basin is 0.18. If the fuel remained wet in the dry basin, the k_{eff} is 0.64. If the center-to-center spacing between fuel on the monorail system decreases to 18 in., the k_{eff} values increase. At this decreased spacing, which is the minimum possible for suspended fuel and matched hangers, in a dry basin, the dry fuel array has a k_{eff} of 0.23, and wet fuel array has a k_{eff} of 0.72.[30]

If the same event that initiates pool draining, such as a major earthquake, also causes the monorail to fail, then the array spacing may be severely perturbed and significant reactivity effects are possible. In this situation, an unplanned criticality must be anticipated. The fuel array would be less reactive after the water drained out and uncovered any fuel lying on the basin floor.

5.1.4 Criticality Accident Logic Matrix

The criticality calculations discussed in Section 5.1.3 are used as bases to determine the potential criticality accidents for the underwater fuel receiving, handling and storage operations at CPP-603. The criticality accident scenarios are summarized in Table VI. As previously stated, the double contingency criteria must be satisfied for criticality accident prevention. Since it is the policy of the current ICPP contractor not to rely solely on two administrative controls for criticality accident prevention, a third administrative control is added to the contingencies in those cases where no physical feature of the system serves as one of the two contingencies. In the case of this fuel storage facility, application of the third administrative control to the contingencies is often necessary, since many operations are administratively controlled.

In each Table VI entry, the accident is identified along with the contingencies. Where necessary, the additional failure is shown under the "Additional Administrative Control" heading in the table. The conditions that are necessary for the criticality to occur given failure of the contingencies are listed in the "required concurrent conditions" column of the table. Each of the table entries is discussed in the following paragraphs, with the section number corresponding to the accident number in the table.

5.1.4.1 Criticality Accident #1. The criticality accidents associated with the ICPP-owned chargers are considered in the appropriate addenda to PSD Section 4.5. The accident described here is included since it can occur at CPP-603, and is the Maximum Postulated Accident (see MPA discussion in Section 6.0). A criticality due to fuel falling out of the bottom of the High-Load charger can be postulated, since the charger can physically hold a quantity of fuel in excess of the minimum critical amount (if optimally arrayed with full water reflection) when the insert is used. In this accident scenario, the loaded charger is being handled and the bottom slide drawer opens, allowing the fuel to fall out into some other water-flooded array. This accident may be subdivided into two separate accidents (as shown in Table VI), one

Table VI. Contingencies Against Criticality Accidents at CPP-603

Criticality Accident	Contingencies #1	Contingencies #2	Additional failure(s)	Required Concurrent Conditions
1. (a) Criticality due to fuel falling out of bottom of High Load Charger.	Failure to properly prepare charger (close slide drawer and install safety bar) prior to start of loading operation.	Failure of second certified person to verify proper preparation of charger.	Opening of the slide drawer.	Formation of critical array must occur. A minimum critical number of fuel pieces must be available from the loaded charger.
(b) Same as above.	Failure of safety bar.	Opening of the slide drawer.	Opening of the slide drawer.	Same as above.
2. Criticality due to alteration of a single FHU by impact of a cask/charger.	Failure to comply with prohibition on placement of cask/charger into an unloading area that already contains fuel. (Failure to inspect area for presence of fuel).	Failure of second certified person to inspect unloading area for presence of fuel.	(Degree of fuel alteration sufficient for reactivity increase to critical).	Fuel piece must contain U-235 mass in excess of single parameter limit.
3. Criticality due to spill of fuel from loaded rack.	Failure to comply with prohibition on lifting or moving of fuel-loaded racks.	Release of rack from lift equipment due to a lift equipment malfunction or a failure of the rack lift points.	Failure second certified person to verify rack loading prior to handling operations.	After release from lift equipment, rack must rotate sufficiently for fuel to spill out. In addition critical array of fuel pieces must form.
4. Criticality due to assemble of critical array in RK-SK-900 rack position.	Failure of certified person to control rack position contents within approved limits	Failure of second certified person to determine compliance with approved loading configuration prior to any fuel loading or unloading operations.	Failure to install criticality control fixture into fully loaded RK-SF-900 rack position when required.	Requires preparation of incorrect RK-SF-900 rack position for loading, and formation of critical array (combination of like or unlike fuels).
5. Criticality in storage rack due to fuel failure.	Failure to maintain water quality. (Operation of water treatment systems, administrative control over additions to basin water).	Failure to monitor basin water quality effect on fuel and storage equipment integrity (by periodic inspection and sampling).	Loss of fuel geometry due to corrosion in basin water environment. Review for materials compatibility.	Failure of single FHU with sufficient water volume fraction and U-235 loading to increase rack array reactivity from K-eff of 0.95.

Criticality Accident	Contingencies		Additional Failure(s)	Required Concurrent Conditions
	#1	#2		
6. Criticality due to placement or drop of fuel on top of an RK-SF-901 rack.	Failure to maintain sufficient water gap thickness over top of fuel stored in rack.	Failure to have handling operation performed by 2 persons certified in fuel handling.	Multiple failures of these contingencies required.	Interactive reactivity between rack array and fuel set on top of rack sufficient for criticality. In drop scenario, release of FHU necessary - possible physical failure of handling tool.
7. Criticality due to placement of drop of fuel on top of RK-SF-900 rack.	Failure to maintain sufficient water gap thickness over top of fuel stored in rack.	Failure to have handling operation performed by 2 persons certified in fuel handling.	Multiple failures of these contingencies required.	Interactive reactivity between rack array and fuel set on top of rack sufficient for criticality. In drop scenario, release of FHU necessary - possible physical failure of handling tool.
8. Criticality due to drop of fuel into open RK-SF-900 rack position.	Failure to maintain rack lids in closed position (except for loading and unloading preparations).	Release of FHU from handling tool results in drop accident.	Failure to insert criticality control fixture into loaded RK-SF-900 rack positions.	(Criticality similar to case 4 above, except physical failure-release of fuel from handling tool required in addition to open rack positions.)
9. Criticality due to. overloaded fuel storage bucket.	Failure to comply with defined fuel loading limits for fuel storage buckets. Failure to have bucket loading operation performed by person certified in fuel handling.	Failure of second certified person to verify compliance with bucket loading limits prior to insertion of each piece into the bucket.	Multiple failures of these contingencies required and fuel in excess of double-batch needed for criticality.	Critical array spacing possible in bucket.
10. Criticality due to drop of fuel from adjacent monorail hanger positions.	Failure to isolate highly reactive FHUs on monorail system.	Release of an FHU from monorail position.	Release of second, adjacent FHU from monorail position (physical failure).	Dropped fuels must fall sufficiently close together for most reactive array.

Criticality Accident	Contingencies #1	Contingencies #2	Additional Failure(s)	Required Concurrent Conditions
11. Criticality due to interaction between fuel on adjacent monorail hangers.	Failure to isolate highly reactive FHUs on monorail system.	Failure to preserve spacing between adjacent monorail positions by use of like hangers.	Failure to conduct periodic inspection to ensure like hangers segregated and unlike hangers separated by an empty bucket.	Mismatch of hangers with respect to bumper design required for loss of isolation between adjacent positions and reactivity of two position fuel array sufficient for criticality.
12. Criticality due to array of more than two FHUs out of approved storage locations.	Failure to comply with single FHU restriction out of approved storage location in each area, except for fuel contained in cask/charger or for FHU assembly or reconfiguration[a] operations.	Failure of second certified person to inspect area prior to removing FHU from approved storage location or cask/charger to verify no other FHU is present in the affected area.	Multiple failures, of these contingencies required and fuel in excess of double-batch needed for criticality.	Wherever possible FHUs defined such that minimum critical number is at least three. It is assumed that an array of two unlike FHUs, each with minimum critical greater than two is critically safe.
13. Criticality due to array of two FHUs out of approved storage locations.	Failure to comply with single FHU restriction out of approved storage location in each area, except for fuel contained in cask/charger or for FHU assembly operations.	Failure of second certified person to inspect area prior to removing FHU from approved storage location or cask/charger to verify no other FHU is present in the affected area.	Failure to comply with additional restrictions limiting fuel out of approved storage to a single FHU anywhere underwater if highly reactive. FHUs in casks/chargers excepted.	Very few FHUs are sufficiently reactive that an array of two like units is at or above 0.95 k-eff (none have k-eff equal or more than 1.00). Reactivity of an array of such a unit and an unlike and less reactive unit generally not determined, but assumed to exceed K-eff of 0.95.
14. Criticality due to only 4-inch separation from edge of RK-SF-900 fuel loaded rack position and fuel external to the rack.	Failure to comply with approved loading limits for the rack position(s).	Failure of second certified person to verify compliance with approved loading limits for the rack.	Multiple failures required; excess reactivity in several rack positions.	Reactivity of rack array dominated by racks in a 2 x 2 -1 array ("L-shaped") with fuel against racks at inside corner.

FHU reconfiguration is an operation in which more than one FHU ... of storage to enable more than one small FHU (or small multiple FHU) to be removed from storage and placed into a fixture/container t... itutes a single larger FHU. An example of this, is the convert ...BR-11 fuel from two four-container "carrier" FHUs to one eight-container... rack insert" FHU (see section 2.2.1.1).

Criticality Accident	Contingencies		Additional Failure(s)	Required Concurrent Conditions
	#1	#2		
15. Criticality due to fuel falling out the top of a shipping cask/charger during handling at the south basin transfer station.	Failure to leave sufficient lid closure devices in place until cask/charger placed on floor in south basin transfer station, when cask/charger contains at least the minimum critical number of fuel pieces.	Release of cask/charger from lift equipment due to a malfunction of the equipment or a failure of the cask/charger lifting points (trunnions).	Failure of second certified person to verify presence of lid closure devices on cask/charger when required.	Rotation of the cask/charger sufficient for lid to fall off; fuel must form a critical array in the water.
16. Criticality TORY-IIA fuel storage array in RK-SF-901 rack due to pool draining event.	Failure of facility to contain water (e.g., loss of facility integrity due to earthquake).	Fail to have TORY-IIA fuel arrayed safely in the rack.		TORY-IIA fuel in close-packed array, wet fuel region and wet buckets, dry or partially drained basin.

arising strictly from a series of administrative failures and the other attributable to an equipment failure.

The failures identified for this criticality accident (which arises from administrative failures) are:

(1) Failure to properly prepare charger (i.e., slide drawer closure and safety bar installation) prior to commencing a fuel loading operation.

(2) Failure of second certified person to verify proper preparation of charger.

Failure to properly prepare the charger is unlikely. Failure of the slide drawer and safety bar mechanism is unlikely since annual inspection of both types of chargers (particularly the slide drawer mechanism and the lid) is required to establish the integrity of the packaging. In this case, the double contingency criteria for criticality accident prevention is satisfied with respect to independence and concurrence.

To satisfy the policy of the ICPP contractor for criticality accident scenarios where the two contingencies are administrative in nature, credit must be taken for the fact that it is unlikely that the slide drawer will open, even given failure to install the safety bar. Commencing of the loading operation with the drawer open is also unlikely since that condition is easily observed.

In the other version of this accident, the charger is properly prepared and the safety bar fails, resulting in a fuel spill provided the slide drawer opens sufficiently. Failure of the slide drawer and safety bar mechanism is unlikely since annual inspection of both types of chargers is required to establish the integrity of the packaging.

5.1.4.2 Criticality Accident #2. A criticality due to alteration of a fuel component is considered a criticality scenario since criticality safety evaluations are based on the design of the fuel structure. A single fuel piece or FHU can contain in excess of the single parameter mass limit for criticality safety, and loss of fuel structure can result in a criticality. In this scenario, loss of fuel structure by a cask or charger impact is the mechanism for the criticality accident. In this

accident a fuel piece or FHU is located in the transfer station
(north or south) and a cask or charger is placed in the selected station
and impacts the fuel piece or FHU already present.

The failures identified for this criticality accident are:

(1) Failure to comply with prohibition on placement of
    cask/charger into an unloading area (station) that already
    contains fuel. (Failure to inspect area for presence of
    fuel).

(2) Failure of second certified person to verify inspection
    prior to placement of cask/charger in the selected
    unloading area.

(3) Degree of fuel alteration sufficient for reactivity
    increase to critical.

Failure to comply with the cask/charger handling restriction
prohibiting placement of a cask/charger into an unloading area that
already contains fuel is unlikely since these operations are performed
by personnel certified in fuel handling. The failure of the verification
by the second certified person is also unlikely. The necessary
independence of the contingencies is provided by the presence of two
certified personnel.

In addition, it is not likely that the fuel alteration will result
in a critical configuration, since the water volume fraction will very
likely decrease. Although lift equipment maintenance and the improper
use of heavy equipment may also be factors in this accident, it most
likely arises from a failure of the two certified personnel to see the
fuel in the station, rather than arising from a cask/charger drop
incident.

5.1.4.3 Criticality Accident #3. A criticality due to spill of
fuel from a loaded fuel storage rack can be postulated since a rack will
commonly contain fuel, although it is rarely moved. This criticality
accident scenario requires simultaneity of two conditions; fuel in the
rack and rack movement. In this scenario the fuel-loaded rack is
hoisted off the basin floor with lift equipment and due to a failure of
either the lift equipment or the rack lift points, the rack is released

from the lift equipment, and in falling, rotates in some manner sufficient to spill the fuel from the rack positions.

The failures identified for this criticality accident are:

(1) Failure to comply with the prohibition on lifting or moving of fuel-loaded racks.

(2) Release of rack from lift equipment due to a malfunction of the lift equipment or a failure of the rack lift points (lifting ears or eyes).

(3) Failure of second certified person to verify status of rack loading prior to rack handling operations.

Failure to comply with the restrictions on rack handling is unlikely since fuel handling operations are performed by, or under the supervision of certified personnel. Similarly, failure to verify the status of the rack loading as specified here is unlikely. A second certified person verifies that the lifting or moving restrictions do not apply since the rack is empty. This operation requires the participation of personnel certified in fuel handling and personnel certified to use heavy lifting equipment.

The necessary physical failure is unlikely, given lift equipment maintenance and testing requirements and rack structural integrity inspection requirements. Corrosion is the probable mechanism of any rack structural failure or deterioration, although rack failure may be attributable directly to the lift if the rack plus contents weight exceeds the maximum design load of the rack lift points.

5.1.4.4 Criticality Accident #4. Criticality in an overloaded rack position is postulated for the stainless steel rack, RK-SF-900, due to the large cross-section (10 x 10-in. square) of the rack positions. Examination of relative FHU size (for those FHUs approved for storage in this rack) and the rack position reveals that there are numerous possibilities for overbatching of the rack position, with combinations of either like or unlike fuels. Based on known critical numbers for specific fuel components, some of these overbatching errors are potential criticality accidents. Even if the overbatched single position k_{eff} were

not 1.00, a criticality might still result due to the contribution of interaction with the remainder of the rack array. Assuming the rack position already contains fuel, this scenario involves preparing the rack position for loading in accordance with the written instructions and adding the additional fuel to the rack position.

Obviously the wrong rack position was prepared for loading -- the instructions were incorrect or, regardless of the paperwork, the position was incorrectly selected in the field. Selection of the appropriate position in the wrong rack is an example of a field error. Preparing the rack position for loading requires opening the rack lid to provide access to the position.

The failures identified for this criticality accident are:

(1) Failure of certified person to recognize significance of rack position contents.

(2) Failure of second certified person to determine compliance with approved loading configuration by visual inspection prior to any fuel loading/unloading operations.

(3) Failure to install criticality control fixture into fully loaded RK-SF-900 rack position when required.

Failure to determine compliance with approved loading configurations for the RK-SF-900 rack prior to any fuel loading or unloading operations is unlikely since fuel handling operations are performed by certified personnel. Similarly, failure to install the criticality control fixture into the rack position when required is unlikely. This fixture, shown in Figure 32, serves as a physical barrier to the insertion of additional fuel into the rack position and is a visual indicator that the rack position (or lower portion thereof, when stacked FHUs are permitted) is to be regarded as fully loaded. Failure of the certified person to recognize the significance of the rack position contents, either when seeing the fuel pieces already present, or the criticality control fixture, is also unlikely. The necessary independence in the contingencies arises from the presence of the second certified person who is independent of the first certified person. The combination of these
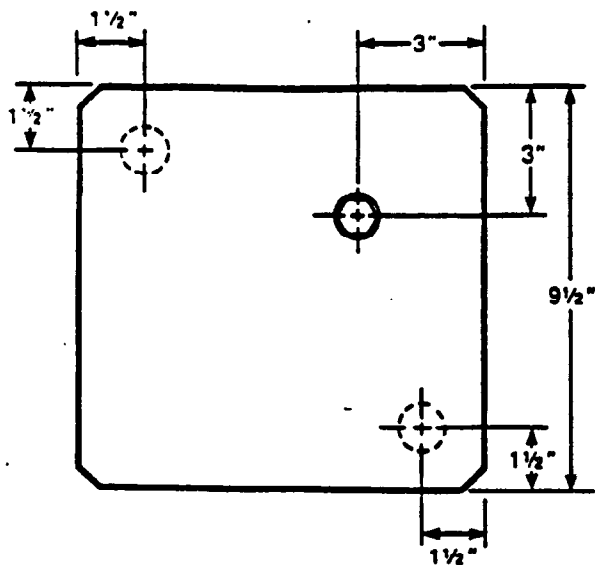
Note: 304L stainless steel for plate and legs. 300 series stainless steel for pickup fitting parts.
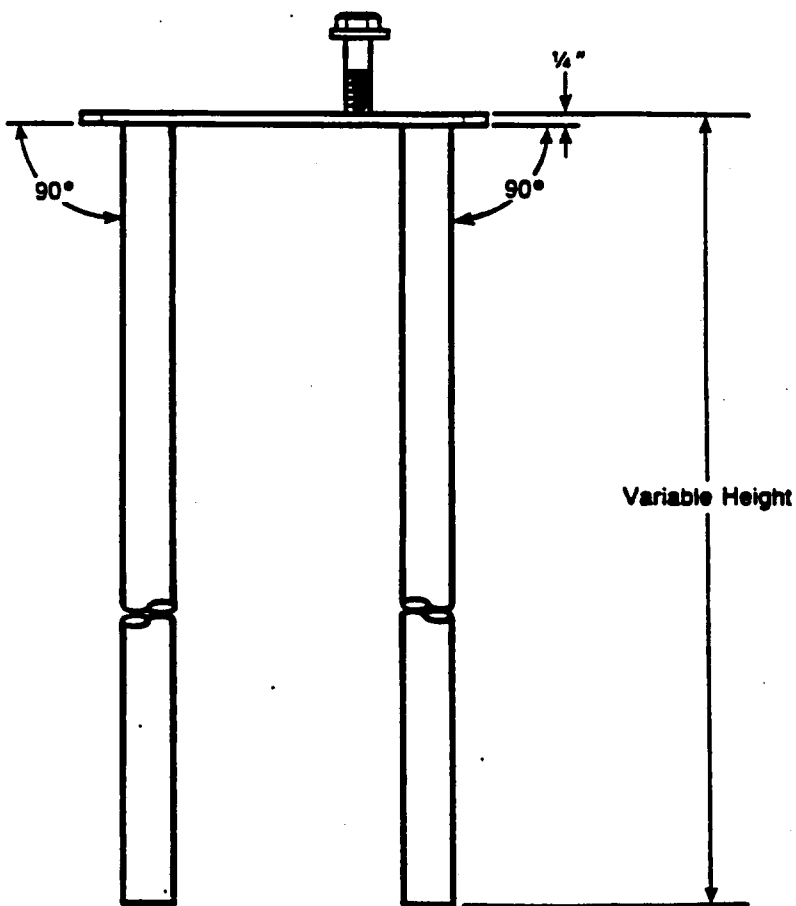
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Figure 32. Criticality Control Fixture for RK-SF-900 Racks

contingencies is sufficient to meet the double contingency criteria for criticality accident prevention.

Note that in this case, a physical barrier to criticality is not being provided, since the use of the criticality control fixture is administratively required. In addition, supervisory approval is required to open the rack lids and to remove the criticality control fixtures when necessitated by a training exercise or an inventory inspection of the rack position contents. Independent verification of the presence of the criticality control fixture (when required) and closure of the rack lids after completion of the operation necessitating opening of the lid is also required.

5.1.4.5 Criticality Accident #5. Criticality in a south basin rack position due to a single failed fuel unit is postulated since the reactivity of fuel is determined (by calculations) on the basis of the fuel geometry. The water volume fraction (in an actual case) would increase in a failed fuel. Fuel failure of this type is considered to be due to a corrosion mechanism, since the fuel would not have been placed into storage in that condition. The scenario for this accident requires deterioration of the fuel structure due to adverse quality of the storage environment.

The failures identified for this criticality accident are:

(1) Failure to maintain basin water quality (operation of water treatment systems and control chemical additions).

(2) Failure to monitor basin water quality (routine sampling) and failure to monitor condition of fuel by periodic corrosion inspections.

(3) Sufficient loss of fuel geometry due to corrosion in basin water environment to cause large increase in reactivity.

Loss of fuel geometry, a physical failure, due to corrosion of the fuel while stored in the basin water environment is unlikely. Although corrosion undoubtedly leads to severe surface defects, e.g., pitting and clad penetration, gross physical defects leading to disassociation of the fuel components is unlikely. In addition, failure to maintain basin water quality in a minimally corrosive condition is unlikely. As

discussed in previous sections of this document, this facility has had a long history of severe water quality problems, and great improvements have been effected by the installation and operation of various water treatment systems. Failure to monitor the overall system, e.g., the basin water chemistry by routine sampling, and the condition of the fuel by corrosion monitoring is unlikely, making this criticality accident scenario extremely unlikely.

5.1.4.6 <u>Criticality Accident #6</u>. Criticality due to placement or drop of fuel on top of an RK-SF-901 rack was considered a possibility.

The failures identified for this criticality accident are as follows:

(1) Failure to maintain sufficient water gap thickness over top of fuel stored in the rack.

(2) Failure to have this operation performed by two persons certified in fuel handling.

These contingencies meet the double contingency criteria for criticality accident prevention. There are two different administrative requirements in effect and there are two people involved in the operation. Multiple failures of excessive fuel height plus failures of the verification are also necessary.

5.1.4.7 <u>Criticality Accident #7</u>. A criticality due to placement or a drop of fuel on top of the RK-SF-900 racks can be postulated, with the same scenario as for the RK-SF-901 racks, above.

The failures identified for this criticality accident are:

(1) Failure to maintain sufficient water gap thickness over top of fuel stored in the rack.

(2) Failure to have fuel handling operation performed by two persons certified in fuel handling.

Failure to maintain a water gap of sufficient thickness over the top of stored fuel is unlikely. Multiple failures of excessive fuel height plus failures of the verification are also necessary.

The water gap parameter is considered in the criticality safety evaluation and the approved fuel listing when storage limits are established. A minimum of eight in. of water gap thickness is specified for all racks on the basis that this amount isolates the rack array and the fuel on top. As indicated in the calculations summarized for this rack, a water gap of six in. is sufficient to meet the k_{eff} of 0.95 criteria for this abnormal condition if the single positions in the array are limited to k_{eff} of 0.916 and 5.0 kg U-235/ft.

The fuel storage parameters established for this rack are the basis of selection of the approved storage configuration (quantity of fuel and geometry) for fuel storage in this rack. Further, these parameters are very conservative since they are derived from the calculations done for three of these racks in an "L-shaped" array with a fuel unit in the inside corner.

In this particular case, credit is not taken for closure of the rack position lids, since the significant parameter is interaction as a function of water gap thickness. The closed rack lids are a physical barrier to dropping fuel into the position, but are not considered to be factors in reducing interaction between the rack array and the fuel on top of the rack, even though stainless steel is not transparent to neutrons. In loading of these rack positions, it is not unlikely that the fuel would rest on top of the rack at some point in the operation. The case where fuel is dropped on top of the rack is less likely since it probably requires the contribution of a physical failure, that of the fuel handling tool, to the scenario.

5.1.4.8 Criticality Accident #8. A criticality due to a drop of fuel into an open RK-SF-900 rack position is very similar to the accident scenario discussed in Section 5.1.4.4 of this section. Criticality in an overloaded RK-SF-900 rack position was considered due to the large cross-section (10 x 10-in. square) of the rack positions. In this scenario, fuel is being transferred over the rack and after a release from the fuel handling tool, falls into an open rack position. Even if the overbatching in this manner does not result in a single position k_{eff}

of 1.00, a criticality can still result due to the contribution of interaction with the remainder of the rack array.

The failures identified for this criticality accident are:

(1) Failure to maintain RK-SF-900 rack lids in a closed position, except for specified loading/unloading, inspection and training operations.

(2) Release of the transferred fuel from the handling tool (either a failure of the tool or the lift point, bail, etc., of the fuel).

(3) Failure to use criticality control fixture in loaded rack position (see Figure 32).

Failure to maintain the racks lids in a closed position is unlikely. Supervisory approval is necessary for opening of the lids and surveillance of the racks is done to ensure that the lids are returned to the closed position after completion of the operation for which they were opened. Release of the fuel from the handling tool is also unlikely. These contingencies are sufficient to meet the double contingency criteria for criticality accident prevention. Not using the criticality control fixture in the loaded rack position is also identified as a failure contributing to this accident.

5.1.4.9 <u>Criticality Accident #9</u>. A criticality accident in a fuel storage bucket can be postulated, and requires overbatching of the bucket. In this scenario, the fuel storage bucket is loaded with the number of pieces defined for a single bucket, and fuel loading continues until the bucket contains in excess of a single bucket limit. In general a bucket is limited to 45% of the minimum critical number of pieces for the fuel component, and overloading in excess of a complete double-batch is required to overbatch to criticality.

The failures identified for this criticality accident are:

(1) Failure to comply with defined loading limits (i.e., in the approved fuel listing) for fuel storage buckets.

(2) Failure of second certified person to verify compliance
      with bucket loading limits prior to insertion of
      fuel pieces into the bucket.

(3) Additional over-batching of the bucket beyond a
      double-batch.

Failure to comply with the loading limits for a bucket loading
operation is unlikely since fuel handling operations are performed by or
under the supervision of certified personnel. In addition, the extent of
bucket fuel handling unit assembly operations at CPP-603 is limited.
Often the fuel will arrive from the shipper in a bucket loaded to the
appropriate limits. Even if the shipped bucket contents are in excess of
the approved loading limits for the north/middle basins, they are not a
criticality hazard, and formation of the approved configuration (division
into two or more storage buckets) can proceed safely given the above
contingencies.

Failure to have such operations performed by a certified person is
unlikely. The failure of the verification by a second certified person
to establish that a violation of the loading limits will occur prior to
loading of an FHU into the charger is also unlikely. These contingencies
are independent of each other. Multiple failures are necessary since a
single overbatch is insufficient to result in a critical mass of fuel.

5.1.4.10 Criticality Accident #10. A criticality due to drop of fuel
(single units or buckets) from the monorail system can be postulated
provided a sufficient amount of fuel is involved. Since bucket loading
limits are generally based on 45% of the minimum critical number of
pieces, either two or more buckets, or two overloaded buckets, are
involved. For single piece fuel handling units, highly reactive fuel
units not properly isolated from each other on the monorail system are
necessary for the accident to occur. This accident scenario involves the
release of a bucket or single fuel unit from the monorail hanger
resulting in a drop of the bucket or single fuel unit to the basin floor.
In the case of multiple fuel pieces in a bucket, formation of the
critical array is enhanced if the pieces spill from the bucket, although
an array of the fuel confined to the buckets can also be critical.

The failures identified for this criticality accident are:

   (1) Failure to isolate highly reactive fuel handling units
        stored on the monorail system.

   (2) Release of the fuel handling unit from the monorail
        position (either due to failure of the hanger, the bucket
        or fuel lift point, e.g., bails or hooks).

   (3) Release of a second fuel handling unit from the monorail
        position (either due to failure of the hanger, the bucket
        or fuel lift point, e.g., bails or hooks).

Failure to isolate highly reactive fuel handling units (defined as FHUs with an array k_{eff} of 0.95 or greater, when the array contains only two such FHUs) from all other fuels on the monorail system is unlikely. These fuels are identified and the storage limits are designated accordingly. In terms of the monorail storage system, isolation of these fuels requires that no fuel be placed in the adjacent positions (on both sides of the fuel) in the same row. With respect to buckets containing multiple fuel units, the loading limits are specified such that the bucket configuration does not become a highly reactive fuel handling unit, meaning that this accident is less probable when involving two buckets.

The equipment failures identified as the additional contingencies must both occur to involve more than one fuel handling unit, and must involve adjacent positions in order for the fuel to form a single array. In addition, the mechanism that causes the failure of the bucket or hanger is most likely corrosion by the water, and there are water quality controls in place to minimize this effect. Defects in the construction of the hangers leading to failure in two positions without detection are also unlikely. Two buckets falling together is considered the maximum accident of this nature due to the fact that there are numerous routine inspections of the facility to monitor water quality, and the integrity of the buckets and hangers. Currently, the CPP-603 basin water is sampled at a frequency of once each month; whereas inspections of the monorail hangers and buckets are conducted annually and include a sampling of each combination of hanger assembly and fuel storage buckets.[44] In addition, materials compatibility, an important factor with

respect to the control of galvanic corrosion damage, is considered in the development of storage modes for various types of fuel.

The double contingency criteria are satisfied for this criticality accident. At CPP-603, there are examples of FHUs in which a water-flooded array of two units exceeds a k_{eff} of 0.95, but the array is not critical (i.e., k_{eff} of 1.00). However, in this accident case the array must be partially reflected by the concrete dividers of the monorail storage systems in the north and middle basins.

5.1.4.11 <u>Criticality Accident #11</u>. A criticality due to interaction between fuel on adjacent monorail hangers is also postulated. This accident is a variation of that discussed in Section 5.1.4.10 above, where the criticality occurs without formation of the fuel array on the basin floor. The accident requires that the k_{eff} of fuel on two adjacent hangers be in excess of 0.95 at optimum spacing and that the optimum spacing be provided. This scenario merely involves storage of highly reactive fuel handling units on adjacent monorail positions using unlike hangers. Unlike hangers have different spacing from the trolley to the lower bumpers and the bumpers will be mismatched. Mismatched bumpers cannot prevent adjacent hangers from approaching closer than 24 in. center-to-center, and possibly closer than 8 in. edge-to-edge.

The failures identified for this criticality accident are:

    (1) Failure to isolate highly reactive fuel handling units stored on the monorail system.

    (2) Failure to preserve spacing between fuel handling units on the monorail system by use of like hangers in adjacent positions; or overlap of hangers.

    (3) Failure to conduct periodic inspection of north and middle basins to ensure that like hangers are segregated into rows and that unlike hangers are separated by an empty hanger and bucket.

Failure to isolate highly reactive fuel handling units (defined as FHUs with an array k_{eff} of 0.95 or greater when the array contains only two such FHUs) from all other fuels on the monorail system, is unlikely. As defined in Section 5.1.4.10, isolation of these fuels means that no

fuel is placed in the adjacent positions (on both sides of the fuel) in the same row. Failure to preserve spacing between adjacent monorail storage positions by using like hangers, and to verify this by periodic inspection of the basins, is also unlikely. Even if two highly reactive FHUs were stored in adjacent positions on mismatched hangers, a criticality is not a foregone conclusion, since the adjacent FHUs are still essentially isolated from each other. In addition, while the maximum k_{eff} of an array of two water-flooded FHUs at CPP-603 exceeds 0.95, it still may not be critical. The increase in k_{eff} resulting from partial concrete reflection does not apply in this case.

The double contingency criteria are satisfied for this criticality accident and the accident is extremely unlikely.

5.1.4.12 Criticality Accident #12. A criticality due to an array of more than two FHUs out of approved storage can be postulated. There are many examples of FHUs where three is the minimum critical number in a water-flooded array. In this accident scenario, a single FHU is out of an approved storage location in a given area of the facility. These areas are defined as the storage basins, the transfer stations and the canal. A second FHU is removed from approved storage, and, if originating from another area, is taken into the area where the first FHU is already present. This action is repeated until there are three FHUs in the area.

The failures identified for this criticality accident are:

(1) Except for fuel contained in casks/chargers, failure to limit fuel out of approved storage locations to one FHU per area (basin, transfer station or canal).

(2) Failure of second certified person to conduct inspection of the area prior to removing fuel from a cask/charger or an approved storage location to verify no other FHU is out of approved storage in the area.

Although only two contingencies are listed, failure to limit the FHUs in the area that are not in approved storage locations or contained in casks/chargers must occur twice in order to form the array of at least three FHUs in the same area. These occurrences are unlikely, as

fuel handling operations are conducted by persons certified in fuel handling operations. Failure to verify, by inspection of the area that bringing an FHU into that area will be in compliance with the single FHU restriction is also unlikely. Fuel contained in casks/chargers is an exception to this contingency. Casks/chargers are not approved storage locations, however the fuel in a cask is shielded by the package design and does not interact with fuel already present in the facility. Bucket assembly operations may require transfer of a fuel piece into an area for inclusion into a bucket that already contains fuel. Consequently it is necessary to interpret "one FHU out of approved storage" as the maximum allowed FHU (not counting each single piece of the FHU).

These contingencies are sufficient to meet the double contingency criteria for criticality accident prevention.

5.1.4.13 <u>Criticality Accident #13</u>. A criticality due to an array of two "high-reactivity" FHUs can be postulated. As discussed above, it is known that two such FHUs may exceed a k_{eff} of 0.95 with full water reflection, although the effect of concrete reflection (as by the floor dividers in the north and middle basins) may be necessary to increase the k_{eff}. The number of such FHUs at the CPP-603 facility is kept to a minimum, and very few of these FHUs are present at any time. The scenario is similar to that developed in Section 5.1.4.12, except that only two FHUs are required for the accident.

The failures identified for this criticality accident are:

(1) Except for fuel contained in casks/chargers, failure to limit fuel out of approved storage locations to one FHU per area (basin, transfer station or canal).

(2) Failure of second certified person to conduct inspection of the area prior to removing fuel from a cask/charger or an approved storage location to verify no other FHU is out of approved storage in the area.

(3) Failure to comply with additional handling restrictions limiting fuel out of approved storage locations or out of casks/chargers to a single FHU anywhere underwater at CPP-603 when that FHU has been identified as a highly reactive unit.

The first two contingencies are the same as those identified in Section 5.1.4.12. In this case, failure of the first contingency need not occur twice. Also, the issue of bucket assembly is academic, in this regard since the loading limits for this type of FHU are established to avoid formation of highly reactive FHUs in the assembly operation. The third failure is an additional handling restriction for highly reactive FHUs and failure is unlikely. These FHUs are identified by the criticality safety evaluations and are added to the approved fuel listing and identified in the handling restrictions as presenting a potential criticality hazard if combined in an array with another FHU.

These failures are sufficient to meet the double contingency criteria for criticality accident prevention.

5.1.4.14 <u>Criticality Accident #14</u>. A criticality accident arising from interaction between fuel in the RK-SF-900 racks and fuel external to an array of racks is postulated. In a 2 x 2 -1 array of three racks, i.e., an "L-shaped" array, with the corner positions of the rack loaded with fuel and a fuel unit against the three racks (in the inside corner), there is 4 in. of water spacing between each of the stored fuels and the external fuel. This spacing does not isolate the stored fuel from the external unit, and as a consequence the overall reactivity of the total fuel array (multiple racks) is dominated by the increased reactivity at this position in the array. As discussed in Section 5.1.3, (Case 7) consideration of this rack array case with respect to allowable single position k_{eff} values, causes this parameter to be limited to 0.88. Failure to adhere to this limit for the stored fuels may result in an unacceptably high (i.e., in excess of 0.95) array k_{eff}.

The failures identified for this criticality accident are:

(1) Failure to comply with approved loading limits for the RK-SF-900 rack position.

(2) Failure of second certified person to verify compliance with the approved loading limits.

Failure to have these operations performed by personnel certified in fuel handling operations is unlikely. The necessary independence of the contingencies is provided by the presence of two certified personnel. Multiple failures of these contingencies are necessary before this criticality accident is possible (i.e., more than one of the involved rack positions must be overloaded).

5.1.4.15 <u>Criticality Accident #15</u>. A criticality due to fuel falling out of the top of a shipping package can be postulated for any cask or charger designed to transport a quantity of fuel in excess of the minimum critical mass (as a minimum critical number of pieces). The High Load charger is an example of such equipment at the ICPP. There are many examples of other shipping casks (non-ICPP-owned) designed to transport large quantities of fuel safely by virtue of certain geometric features and/or fixed poisons. Fuel that falls out of the such a charger or cask is no longer controlled by these design features. In this scenario the cask/charger is somehow rotated sufficiently about its center of gravity that the lid, if improperly secured, falls off and the fuel falls in the water.

The failures identified for this criticality accident are:

(1) Failure to secure the lid properly onto the cask/charger body. (This includes both the case where an insufficient number of lid closure devices are used or they are entirely lacking).

(2) Release (i.e., "dropping") of the cask/charger from the lift equipment, due to a malfunction of the equipment or a failure of the cask/charger lift points (trunnions or lifting ears).

(3) Failure of second certified person to verify presence of sufficient lid closure devices.

The released cask/charger then rotates sufficiently about its center of gravity so that the lid falls off, and the fuel falls out. Release of the lid from the cask/charger either occurs because of the absence of the closure devices or physical failure (e.g., bolt shearing) of the inadequate number used. This scenario is developed for cask and charger handling only at the south basin transfer station which is a large open pool. Rotation of the cask/charger sufficient to spill the fuel is not

possible in the north basin transfer station pit, due to the relatively close fit the cask/charger with the pit cavity. In addition, closure devices cannot be left on casks/chargers until they are placed on the floor of the north transfer station pit due to the design of the cask handling equipment used in the pit.

These contingencies are sufficient to satisfy the double contingency criteria for criticality accident prevention since they are independent, unlikely and must occur concurrently. The failure to secure the lid is unlikely since certified personnel perform these operations. The major contributor to this accident, release of the cask/charger from the lift equipment is also unlikely. Maintenance of lift equipment on a periodic basis is required at the ICPP to ensure the integrity of cranes, hoists and auxiliary equipment. The necessary load-testing and inspections of this equipment are administratively controlled. Likewise, fuel shipping packages, casks/chargers, are inspected, tested and maintained in compliance with the applicable DOE Orders and NRC regulations. Furthermore, personnel operating heavy lift equipment must be certified in the use of such equipment, minimizing the probability of a contribution to this accident from improper operation of lift equipment.

5.1.4.16 Criticality Accident #16. A criticality accident in the TORY-IIA fuel storage array is postulated due to the results of specific criticality calculations performed to evaluate the effect of a pool draining accident on the reactivity of stored fuels. As indicated in Section 5.1.3 (Case 14), close-packing of the TORY-IIA fuel in the RK-SF-901 rack is a potential criticality problem if water remains in the fuel and bucket region, and the basin is partially or totally drained of water. Regardless of the degree of fuel/bucket flooding as compared to the basin water level, the TORY-IIA fuel storage array poses no criticality hazard if the empty rack positions (leftover from close-packing of the fuel into the rack) are distributed into the fuel array. Two alternate distributions, a checkerboard mixing, or use of the empty positions to form an unoccupied region in the rack that was positioned between two halves of the fuel array, were effective in reducing array k_{eff} values.

The failures identified for this criticality accident are:

(1) Failure of the CPP-603 basin facility to contain water (possibly arising from an earthquake of sufficiently large magnitude).

(2) Failure to have the TORY-IIA cans distributed in the RK-SF-901 rack in a safe array.

These contingencies are unlikely, independent and must occur concurrently. Although the facility is vulnerable to earthquake-induced failures that may result in loss of water, it is unlikely that an event of sufficient magnitude will occur during the remaining life of the facility. The TORY-IIA cans in the dedicated RK-SF-901 rack have been distributed into a safe configuration.

5.2 RADIOLOGICAL SAFETY

This section includes a discussion of radiological protection criteria, radiological hazards (direct radiation and contamination) and control methods.

5.2.1 Radiation Protection Criteria

The radiation exposure of personnel in the CPP-603 underwater fuel storage facility is maintained as low as reasonably achievable, i.e., "ALARA," through the application of a vigorous radiation control program by operating personnel and line management in accordance with standards developed by resident radiological experts at the ICPP. The radiation protection criteria for the CPP-603 underwater fuel storage facility are in accordance with the ICPP Radiological Controls Manual[1] and the applicable DOE Order.[31] These documents provide the limits for radiation exposure in terms of dose equivalents, to an on-site worker.

In addition to limits for occupational radiation dose, annual dose limits are specified for radiation doses to off-site individuals and population groups in DOE Order 5400.3.[32]

5.2.2 Radiological Hazards and Control Methods

The principal radiological hazard at the CPP-603 underwater fuel storage facility is direct radiation, either from the fuel, the basin water, or from contamination.

The direct radiation exposure hazard is somewhat mitigated by the duration of the out-of-reactor cooling time for a fuel prior to shipment to the ICPP. Most fuels are cooled for at least 100 days before shipment to the ICPP. A cooling period of this duration permits decay of the inventory of short-lived fission and activation products, thereby reducing the direct radiation hazard. Long cooling periods also significantly reduce the decay heat generation rate of the fuel. Generally, fuels received at the ICPP for underwater fuel storage have been cooled for at least one year. EBR-II fuel, on the other hand, is received at the ICPP with a minimum of 20 days of out-of-reactor cooling. With a cooling period of such short duration, EBR-II fuel shipments are limited by the shipper with respect to a total decay heat generation rate in each shipment.

Regular inspections by corrosion specialists to determine current integrity of storage equipment and fuels are an indirect method of mitigating direct radiation exposures from the water. These inspections have revealed developing problems that can lead to release of fission products to the water from the exposed fuel surfaces. Aside from contaminating the water with the fission products, this process also causes the water to be a source of direct radiation.

Routine surveys of each working area in the facility, for direct radiation and contamination hazards, allow marking, tagging, and isolation of the radioactive sources for subsequent shielding and/or removal. Personnel dosimetry devices are worn by all individuals within the facility (e.g., regularly assigned operating personnel and incidental visitors). These devices serve both to monitor the radiation sources within the facility and to record individual exposures for exposure control. Permanently placed dosimeters (NADs) are also located in the facility work areas to record radiation levels from major accidents.

5.2.2.1 <u>Direct Radiation Exposure from Fuels</u>. The fuel storage basins
are designed to contain a maximum depth of 20 feet of water to provide
gamma-ray shielding. The normal depth of about 19 feet provides from
6 to 16 feet of water shielding for personnel during fuel handling.
Maintenance of this water barrier is the major protection against direct
radiation exposure from fuels. Several administrative as well as
physical controls are imposed to maintain this water barrier. Figures 33
and 34 show the relative direct radiation fields from fuel as a function
of water depth over the fuel.[33,34] In each case, the dose rate is for a
single fuel handling unit. The dose rate function is very similar for
the ATR and EBR-II examples shown in these Figures, in spite of the
difference in cooling times.

The dose rate from a criticality accident is discussed in
Section 6.1.2.2 as part of the quantification of the effects of the
maximum postulated accident (MPA). In the MPA, the accident analyzed is
one that has both local facility and off-site effects. The radiological
effects of an accumulation of unshielded fuel (e.g., fuel that falls out
of a shipping package onto an aboveground, not an underwater, surface)
are also discussed in Section 6.1.2.2 as part of the radiological risk of
operating this facility.

Fuel handling operations are monitored continuously for radiation
fields by a Health Physics technician whenever fuel components are raised
from the storage location up to an elevation where the water shielding
thickness over the active fuel region approaches 6 ft. Similarly,
removal of any fuel handling or transfer equipment from the basin water
(casks, handling tools, etc.) requires Health Physics technician
monitoring to determine the extent of decontamination and handling
procedures required prior to removal of this equipment from the facility.

To ensure that the water is maintained at an adequate depth, the
transfer canal contains a water-level indicator that alarms locally and
at the Central Facilities Fire Station. The water level can be
controlled by adding raw water or water from the reverse osmosis
demineralization system.
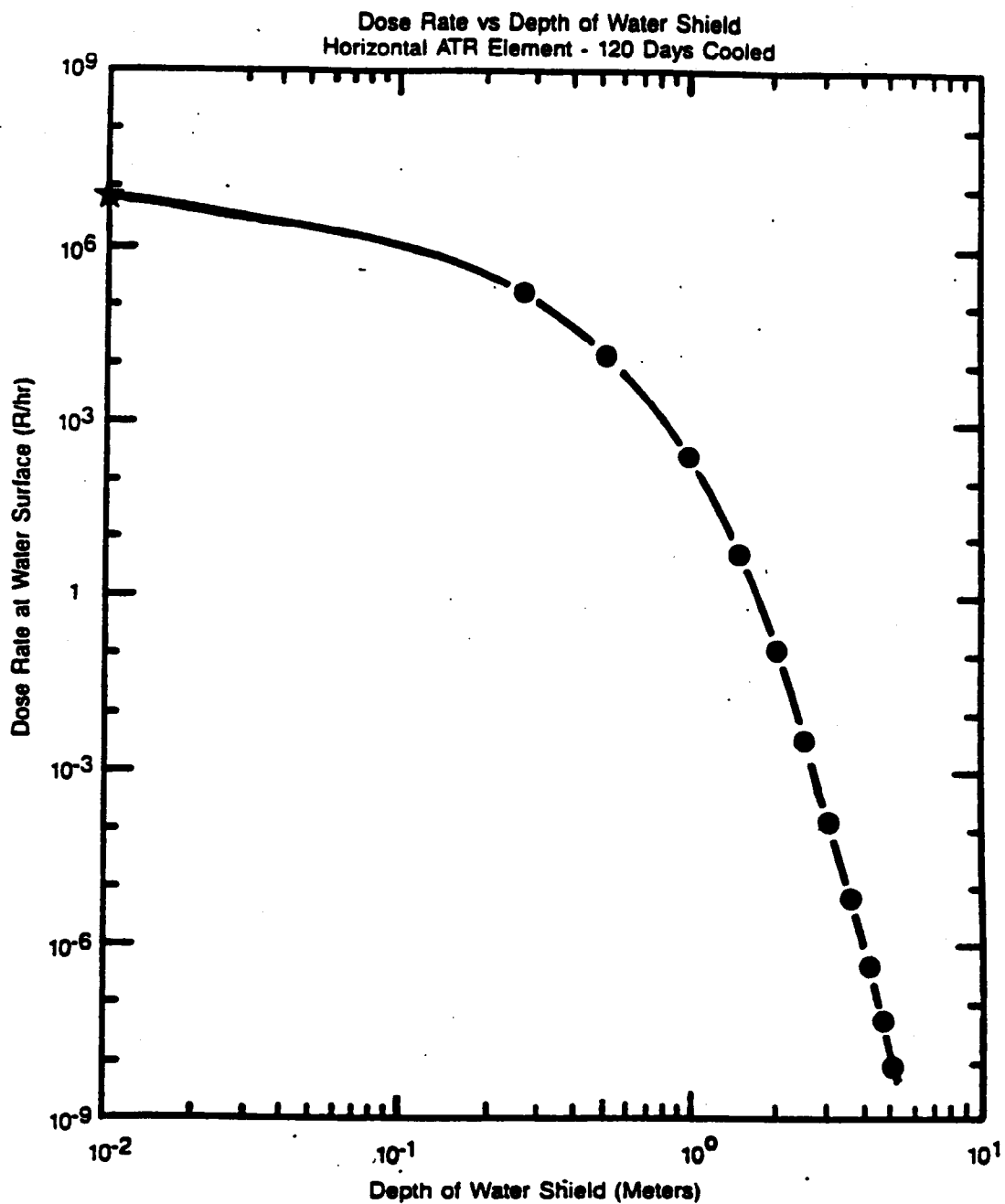
Figure 33.   ATR Dose Rate as a Function of Water Shielding Depth
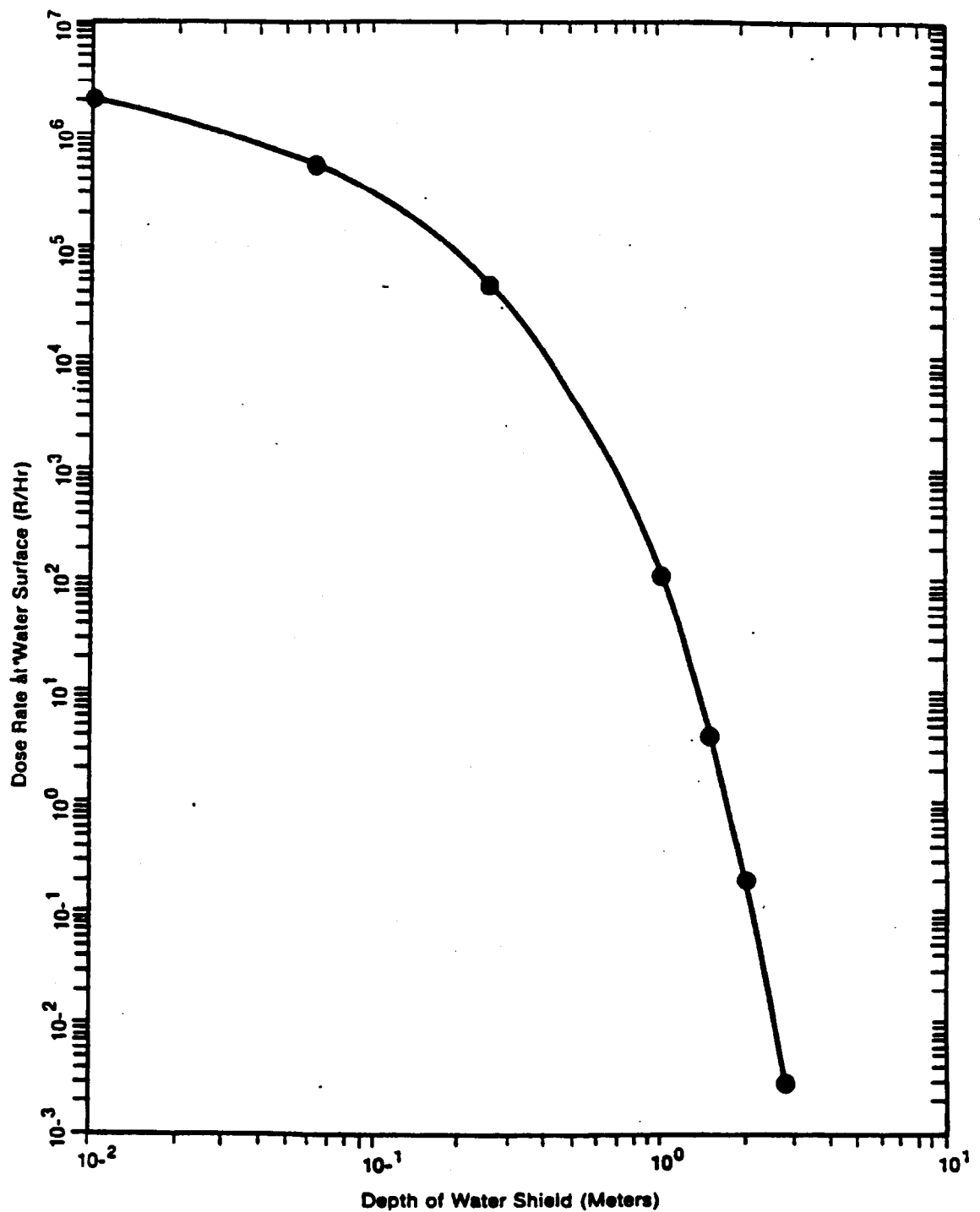
Figure 34. EBR-II Dose Rate as Function of Water Shielding Depth

Cracks in the basin floor or walls, through which measurable losses of basin water could escape, have not been observed or detected. Should such a crack occur and should water makeup be insufficient to maintain the water level, the fire truck pumping capacity could be used to increase the water supply.

To ensure that radioactive fuels are not inadvertently raised above a minimum water shielding depth (with respect to keeping cumulative radiation exposures in compliance with guidelines specified by DOE and the current ICPP contractor), the fuel is normally handled with specially designed and/or marked underwater handling tools.

Occasionally fuel assemblies are lifted with electric or hand-operated chain hoists. All power devices for lifting fuel in the basin, including the basin crane, are designed with special lifting tools that are sufficiently long such that the top of the active fuel sections remains 6 ft below the surface of the water. The upward travel limit is established by the physical limit of the lifting device. The use of this type of hoist for lifting of fueled components is prohibited unless a Health Physics technician monitors the operation.

Lateral shielding of radiation from the fuels is controlled by having all but 3 ft of the basin below grade. Additional lateral shielding is provided by earthfill around the above-grade portion of the concrete basin walls. Radiation surveys are routinely conducted around the area to ensure that radiation levels have not become excessive. All fuel and cans of fuel received for storage are required to have sufficient density to prevent self-buoyancy, even if the void space is filled with a gas.

The ICPP-owned chargers must be labeled "LOADED" when they contain fuel. All casks/chargers are labeled "EMPTY" as soon as they are unloaded, withdrawn from the basin, and decontaminated. Any unlabeled cask is considered loaded unless verified to be empty by underwater inspection or by some other approved method.

Shortly after arrival at the ICPP main gate, incoming fuel shipment casks are monitored for direct radiation and radioactive contamination.

Casks/chargers leaving the CPP-603 basin also are surveyed for direct radiation and for radioactive contamination. Radiation and contamination levels of both incoming and outgoing shipments must be within the guidelines specified by the current ICPP contractor.[1] Off-site shipments and on-site (outside of the ICPP perimeter) must meet the applicable DOE and NRC criteria.

5.2.2.2 <u>Direct Radiation from Basin Water</u>. Direct radiation from the basin water arises from the radionuclides that are dispersed into the basin water and through the associated water cleanup systems and adsorbed onto surfaces of the basin walls. Direct sources of radionuclide introduction into the basin water include cask coolant or failed fuel (breached cladding), or fuel cladding activation products. Introduction of radionuclides via cask coolant is prevented by sampling of the fluid. If excessive contamination (greater than current basin water levels or greater than normally encountered for the particular fuel type) of the fluid is found, the coolant is drained or flushed from the cask to the hot waste tank, VES-SFE-126. This prevents uncontrolled release of the radioactivity to the basin water. Dry casks that appear to be pressurized must be vented through a HEPA filter prior to immersion in the basin water.

Aside from contaminated coolant, there is a potential for incoming casks to contain heated fuel which may also introduce radionuclides into the basin water. Some casks are shipped dry and the contents could become overheated due to loss of air cooling, loss of a liquid coolant or from having an excessive heat flux. All thermally hot fuels are cooled before immersion of the cask into the water. Wet shipments are not drained (a loss of coolant), but are backflushed to replace the coolant, thereby keeping the cask contents in contact with a cooling liquid.

Radiation from contaminated basin water contributed about 50% of the personnel exposure in the operation of this facility in previous years when the water quality was relatively poor (as is apparent from the radionuclide concentrations in the water reported for 1976 and 1980 in Table I). The other 50% came from contamination accumulations at or above the water line. Both of these major sources arose from leaking

fuel. Until the water contamination situation was improved, radiation exposures were controlled by strictly limiting the working time of the available fuel handling operators. As previously stated, each person working in the basin area is required to wear dosimetry devices as directed by a Health Physics technician. These dosimeters record radiation exposure during operational activities and provide a continuing check on the exposure levels. These general practices are still applicable at this facility, even though the radiation hazard from the water has been greatly reduced by the improvements in the water treatment systems.

Prior to a new fuel receipt at this facility, the fuel is evaluated to determine the expected storage time in the CPP-603 underwater fuel storage facility, considering the corrosion potential of the basin water.

It is the policy of ICPP management and the local DOE field office to require that ICPP fuel storage facilities that are dedicated to the storage of processable fuels be limited to storing only those fuels that can be processed within five years. In regard to the estimated storage time, it is intended that fuel in storage at the CPP-603 basins be processed within that time, or disposed of to another fuel storage facility. This can entail removal from the ICPP entirely (e.g., shipment to another INEEL facility or shipment off-site) or transfer to dry well storage (underground) at the ICPP.

Packaging (or re-packaging as the case may be) of fuel to extend its storage life with respect to containment was not routinely done in this facility. Severe deterioration of fuel containment, be it cladding or cans, has been observed in many fuels stored at the CPP-603 underwater fuel storage facility in excess of 20 years. The deterioration has occurred as a direct result of the corrosive water environment, with some contribution from interaction of dissimilar metals (e.g., galvanic corrosion due to incompatible fuel clad or can and storage equipment materials). The aluminum-clad TRIGA fuel is considered, through observation only, to be a severe example of such deterioration. Therefore, TRIGA fuels have been repackaged and oved to the south basin.

Severe leakage of EBR-II fuel assemblies at CPP-603 occurred in the mid 1970s, resulting in canning of the fuel prior to shipment.

Although the current situation with respect to the deteriorating fuels in storage, is believed to be stable due to the improved quality of the water, removal of those fuels, which are not processable or which, for various reasons (e.g., processing schedules and economics) have not been processed, to dry well storage at the CPP-749 area, is a long-term goal. Whereas removal of this fuel from the facility will reduce the potential for radionuclide leakage from this source in the long-term, the actual handling involved with this operation will undoubtedly lead to increased radiation exposures. Handling of the more severely distressed specimens may cause them to fragment, dispersing uranium and radionuclide particulates into the water.

In addition to practices and procedures to prevent introduction of radioactive materials into the basin water, the water treatment systems function to reduce the basin radioactivity by removing existing dissolved and entrained materials. As discussed previously (see Section 3.5), the water treatment systems currently in operation include the multimedia filter system and the two ion exchange systems. Monthly monitoring of basin water provides a measure of the progress of water quality · improvement. Monitoring of radioactivity in the removal equipment (filters and exchangers) indicates the amount of radioactivity removed from the basin water. The monitoring results are used to determine flushing and regeneration cycles for the removal equipment.

Hard-water scale that forms on the basin walls above the water surface contains significant amounts of occluded radioactive materials that contribute to the exposure rates in the transfer canal area. In the past, the basin water level was lowered and the walls cleaned in an attempt to reduce the radiation from this source. Following cleaning, a water-resistant paint was applied to permit routine removal of further scale buildup. This action, however, proved to be insufficient for lowering the radiation level. Shielding with Pb-Al decking laid over the transfer canal grating has proved to be beneficial in lowering the radiation exposure to fuel handling operators. Regular, routine surveys

by health physics technicians monitor this and other radiation sources in the facility.

The sludge removed from the basin is highly radioactive and is stored underground in VES-SFE-106 (the 25,000-gal sludge storage tank, shielded with 4 ft of earth and 2 ft of concrete). Methods for permanent disposal of the contained sludge and spent resins will be developed before VES-SFE-106 approaches the end of its useful life. Recently, 1986-87, an outside contractor performed a sludge and resin removal (from VES-SFE-106) operation.

5.2.2.3 Contamination Control. Radioactive contamination must be controlled to minimize exposures to plant personnel. Fuel shipment casks are surveyed and decontaminated as necessary before and after delivering fuel to CPP-603. Contaminated basin water is drained from all casks when they are removed from either transfer station. A continuous clean-water spray is used to wash the basin water (i.e., the source of the contamination) from the cask as it is suspended above the water. Additional water sprays and handwiping are performed when necessary to decontaminate to required levels.

A change room has been provided for CPP-603 operating personnel in the CPP-626 building. This provides a barrier to radioactive contamination that might otherwise be transferred inadvertently to other ICPP areas by personnel that travel between CPP-603 and these other work areas.

When removed from the basin, all off-site casks are decontaminated to within DOE and NRC requirements. On-site casks are wrapped in plastic, if necessary, to bring their surface contamination levels within the applicable on-site requirements. A drip pan is placed on the carrier vehicle beneath on-site casks to catch any contaminated water that may escape the cask or its plastic wrapping. Similarly, any equipment removed from the basin water, or that has been in contact with the basin water, is washed with a clean water spray, wiped dry, decontaminated, and wrapped in plastic, if necessary, before it is removed from CPP-603. Solid wastes (e.g., blotting paper and shoe covers) removed from CPP-603 are taken to the Waste Experimental

Reduction Facility (WERF) for disposal. Fuel transport casks, the hot waste tank, VES-SFE-126, sludge storage tank, VES-SFE-106, pressurized filter tanks, and other vessels having a potential for airborne contamination are vented through HEPA filters to the environment.

5.2.2.4 <u>Radiation Exposure from Auxiliary Systems</u>. The two ion-exchange systems at the CPP-603 underwater fuel storage facility are potential sources of radiation exposure, since fission products are intended to accumulate in these systems. The ion-exchange resin beds continuously remove Cs-137 and Sr-90 (as well as other cations) from the basin water. Typical exposures to personnel from the changeout of the resin beds in the old ion-exchange system (Cs-137 removal) are about 20 mrem.

The resin beds in the old ion-exchange system, in VES-SF-101 and -102, one of which is charged with PDZ-14010 (the other is empty) for Cs-137 removal, are located behind 24 in. of concrete, thereby protecting operators from the 0.66 MeV gamma radiation emitted by Cs-137. However the top of the ion exchanger vault is not shielded as thoroughly and some scattered radiation is possible from the roof over the cell. If the design quantity of Cs-137 (650 Ci) were contained on the resin bed, the scatter could contribute about 4 mrem/hr to an operator at the side of the cell. If both of the old exchangers are charged with a resin for cesium removal, the design quantity of Cs-137 contained in the cell is assumed to be doubled (to 1300 Ci), thereby doubling the dose rate from scatter to 8 mrem/hr. A typical body field is 7 mRem/hr. It is unlikely that the fully charged beds would ever contain the design quantity of Cs-137 since there is competition for the resin by other cations, e.g., sodium and calcium. Exposures to personnel associated with the changeout of the resin beds in the new system are about 20 mrem for either the Duolite 464 resin (Sr-90 removal) or the Zeolon 900 resin (Cs-137 removal). However, the Zeolon 900 resin is changed more frequently because it is not regenerated.

The new, larger ion-exchange system, containing VES-SF-131 and -132 (see Figure 3) is located in the ion exchange room south of the old vault. The piping, pumps, and vessels of the new ion exchange system are

shielded with 1/8-in.-thick lead, 8-in.-thick concrete blocks, and 3-foot-thick concrete walls, respectively. The facility was designed to allow a maximum exposure to personnel of 0.6 mrem/hr with an occupancy rate of 25% even if the design quantity of activity (1500 Ci) is present on the resins of the new system. Radiation levels of the two parallel-operated resin beds are monitored routinely. The Duolite 464 resin, used in VES-SF-131 to remove Sr-90, is regenerated as needed; the Zeolon 900 resin, used to remove Cs-137 in the other three exchanger vessels, VES-SF-101 (PDZ-14010 resin bed in 1988), -102 (empty and in standby in 1988), and, -132, is replaced when breakthrough of cesium occurs.

5.2.3 Radiological Safety Features and Instrumentation

The major categories of radiological safety features are as follows:

- Facility design, including water and decking for shielding,

- Monitoring of fuel handling operation (health physics technician surveys, corrosion surveillance, and water quality sampling),

- Decontamination equipment and procedures (cask rinsing and decontamination pad),

- Fuel handling equipment design,

- HEPA filtration of vents from potential sources of airborne contamination, and

- Instrumentation (water level monitor, CAS, CAMs/RAMs, and permanent dosimeters).

These features have been mentioned in the previous discussion on radiological hazards and control methods; only the instrumentation is discussed in more detail here.

5.2.3.1 Instrumentation. Aside from the various practices and procedures employed at the CPP-603 underwater fuel storage facility, safe operation with respect to undesirable radiation exposure to personnel is dependent on the operability of specified instrumentation. This instrumentation has been identified previously in the Group I instrument listing, Table IV. The operability of these Group I

instruments is essential to providing a warning system to personnel of an abnormal occurrence that could result in high radiation fields and/or releases of airborne activity to the immediate area and to the environment.

A CAS is not required by DOE Order 5480.24; however one has been installed in the CPP-603 underwater area, since amounts of fissionable materials in excess of 700 grams of U-235 (or equivalent) are routinely handled. The CAS was installed even though the thick water slab, 13 feet minimum above the stored fuel, would attenuate the effects (radiation dose and fission product release) of a criticality accident. The CAS will not detect a criticality that occurs on the basin floor.

There are five detectors for the criticality alarm system in this area., CAS-SF-51, -52, -53, -54, -55. The alarm logic is designed such that any two of the five detectors alarming simultaneously will activate the facility evacuation alarms, i.e., a 2-out-of-N logic. Due to the location of these monitors, shown in Figure 35, at least four of the five detectors must be operable when initiating a fuel handling operation. In addition, the two detectors at the transfer station must be operable prior to fuel handling operations in the station to provide sufficient coverage such that a criticality there will activate the evacuation system. Similarly, the detector associated with the south transfer station must be operable prior to fuel handling operations there, so that two detectors, the second being at least one of the detectors at the west end of the south basin (CAS-SF-54 or -55), are monitoring the station.

In addition to actuating an evacuation alarm at the CPP-603 building, the trip condition is also transmitted to the CPP-601 evacuation system for a total plant evacuation. The operability requirements of the system are tied to fuel handling operations, since this is when the risk of a criticality becomes greatest. Completion of an operation already in progress when the system becomes inoperable is allowed, since a safe configuration will result from a properly completed operation and abandoning an operation in progress may lead to confusion when it is later resumed.

CPP-603

CAM Areas

1. Sand filter area
2. South basin area
3. Chloride removal deck
4. Ion exchanger room
5. Decontamination pad
6. North deck
7. South loading deck
8. Middle deck

CAS Criticality alarm system detector

LA Level instrument
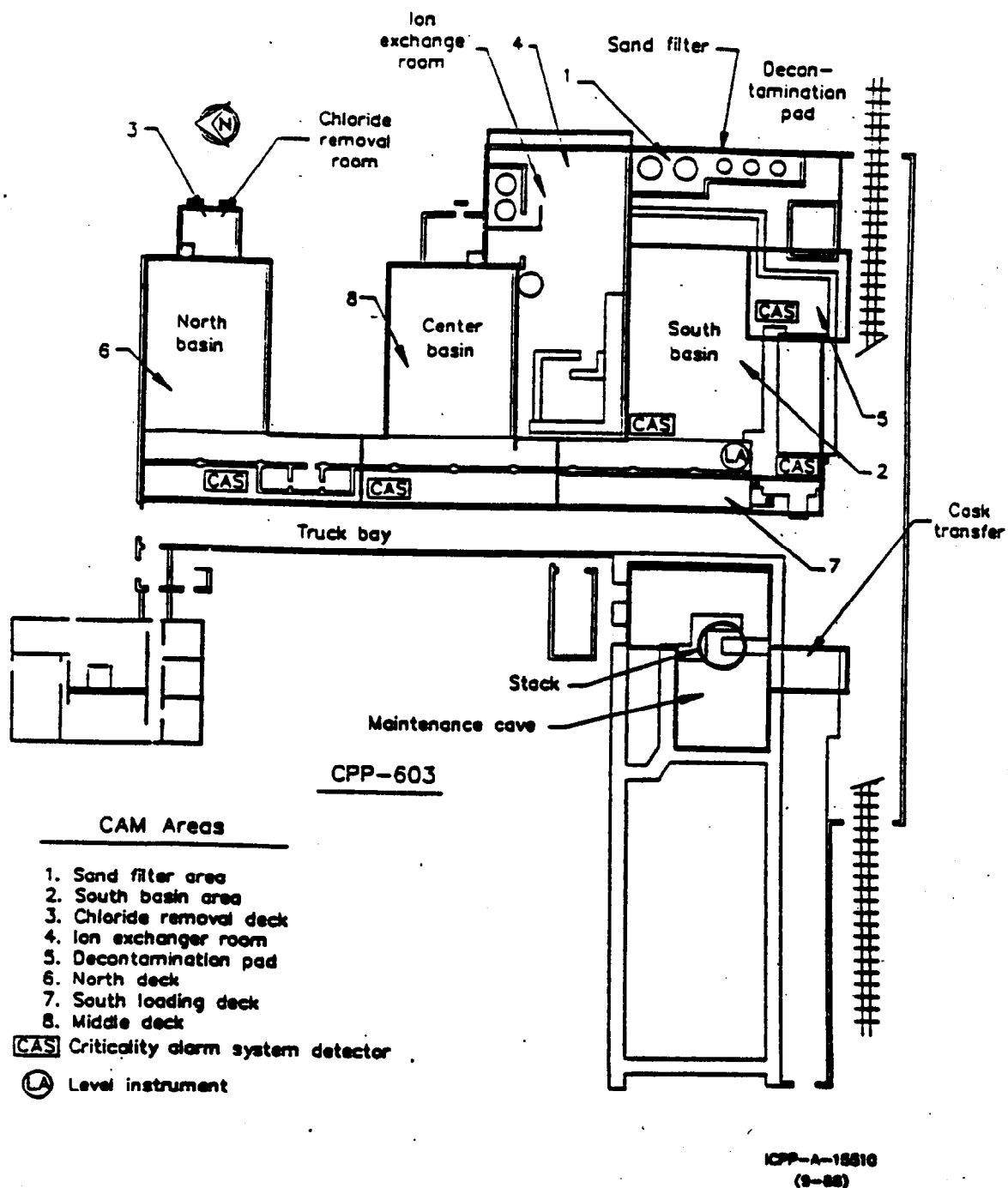
ICPP-A-15810
(9-88)

Figure 35. Approximate Location of CPP-603 Group I Instrumentation

These five direct CAS radiation monitors at the CPP-603 facility, are dual purpose instruments, functioning also as Remote Area Monitors. These instruments have an operating range of 0.1 to 10^4 mR/hr and will alarm if fuel is raised too close to the water surface. This CAS is supplied with emergency and backup power (batteries maintained by a trickle charger).

There are seven continuous air monitors (CAMs) at the CPP-603 underwater fuel storage area located in the following general areas; multimedia filter area, south basin, chloride removal area, ion exchange room, decontamination pad, north, middle and south portions of the loading platform (see Figure 35). These instruments monitor airborne radioactivity in the immediate vicinity. Radionuclide accumulation in the water treatment areas and potential releases due to fuel handling in the other identified areas are the bases of siting of the CAMs.

In this facility, the sources of airborne activity are releases of volatile fission products from fuel, suspension of particulate contamination, and evolution of volatile fission products from a criticality accident. Aside from detecting air activity and alarming, the continuous air monitors provide a record of air contamination levels, which could be used to estimate abnormal releases to the environment. Since the CPP-603 underwater fuel storage facility is a low-occupancy area and a low-activity area, with few personnel present at any time, operability of any five of the seven CAMs is sufficient to permit initiation of fuel handling operations in the facility. Again, as is the case for the CAS, completion of a fuel handling operation already in progress is permitted if less than the required number of CAMs is operable.

The level instrument, LA-SF-NB-002, a probe which monitors basin water level, is located outside of the south basin proper near the ultraviolet light sterilizers (see Figure 35). The underwater fuel storage facility was designed for a maximum 20-foot water depth to provide gamma-ray shielding. The normal operating depth of 19 feet provides 6 to 16 feet of water shielding during fuel handling operations. Loss of water immersion of the level instrument breaks the circuit

between the level instrument probes and activates an audible alarm. The alarm and the instrument electrical supply are connected to the emergency power system, so that loss of power does not result in failure of the instrument.

Monthly checks of the level alarm are conducted by the LMITCO alarm shop because the alarm is also activated in the Central Facilities Area (CFA) Fire Department, which has been designated as an emergency source of makeup water for the CPP-603 underwater area if a major leak occurred while the area was unattended. Testing of the instrument alarm function is conducted by simply pulling the probes out of the water. The probes are normally immersed to a water depth of 18 in.. Loss of operability of the instrument or any of its components must be corrected within a reasonable length of time. Monitoring of the level at hourly intervals by an alternate method (dipstick) is an adequate backup measure.

5.3 INDUSTRIAL SAFETY

The industrial safety topics discussed in this section are those that impact the safety of operation of the CPP-603 underwater fuel storage facility and that are non-nuclear, e.g., not specifically related to criticality or radiation/contamination safety. The specific areas of industrial safety considered here include the following:

- Chemical safety,

- Fire and explosion safety,

- Personnel health hazards,

- Preventive maintenance,

- Water quality control, and

- Corrosion inspection.

5.3.1 Chemical Safety

A limited number of chemicals are used at the CPP-603 underwater fuel storage facility, either in the water treatment systems or as cleaning/decontamination agents. These chemicals are nitric acid, oxalic acid, methyl chloroform, ammonia/detergent (in commercial glass/mirror cleaner) and detergent solution (in "Butcher Block", also a commercial cleaner).

The hazards associated with each of these chemicals are identified in the ICPP Industrial Safety Manual[36] and in Material Safety Data Sheets.[38] The ICPP toxicity classification guide[36] provides a list of chemicals identified as high, moderate or low toxicity hazard and skin toxicity hazard. A chemical classed as "high" is a highly toxic chemical that can result in death or permanent injury to an individual exposed to a hazardous concentration. A "moderate" toxicity rating is given to a chemical causing reversible or irreversible biochemical changes to an individual exposed at hazardous concentrations, but not necessarily resulting in permanent injury or death. A "low" toxicity chemical can cause readily reversible tissue changes and some discomfort from exposure. A chemical classed as a "skin" toxicity hazard can cause reversible or irreversible biochemical/physical changes through contact with the skin or mucous membranes. Such a chemical can also exert a toxic action through inhalation or ingestion. The toxicity classifications, high, moderate and low, are also associated with Threshold Limit Values (TLVs) in terms of ppm, mg/m^3 or mppcf (million particles per cubic foot of air). In addition to designating toxicity on the basis of TLVs, any material that is a known/suspected carcinogen, mutagen or teratogen is classified as a highly toxic material regardless of the TLV.

The hazards associated with the chemicals used at the CPP-603 underwater fuel storage facility are summarized as follows:

1. <u>Nitric Acid</u> This chemical is classed as highly toxic with skin toxicity, and it is corrosive to all body tissues. Although nonflammable in itself, it is a strong oxidizer and may result in fires when in contact with organic materials. For example, cleanup of a nitric acid spill with paper increases the flammability of the paper.

2. <u>Oxalic Acid</u> This chemical, also referred to as ethanedioic acid (HO_2C-CO_2H), is classed as moderately toxic. Oxalic acid is a reducing agent. It is stable at room temperature and decomposes when heated to form CO, CO_2, water and formic acid. Oxalic acid reacts violently with furfuryl alcohol, and reacts with some silver compounds to form silver oxalate, an explosive material. It reacts explosively with chlorites and hypochlorites. Ingestion of a small amount (5 grams) has been fatal, and prolonged skin contact results in dermatitis and cyanosis of the fingers.

3. <u>Methyl Chloroform</u> Methyl chloroform is used as a degreasing agent and is classed as moderately toxic. However, methyl chloroform is relatively low in toxicity for a chlorinated hydrocarbon. It is a colorless liquid with a mild, sweetish pleasant ether-like odor and is intoxicating when inhaled, necessitating its use in a well-ventilated area. Respiratory protection is also recommended. Methyl chloroform is nearly nonflammable and attacks natural rubber. It reacts with water to form hydrochloric and acetic acids. When handling this material, personnel should wear gloves and apron, etc., which are not fabricated from natural rubber. Methyl chloroform defats the skin on contact causing dermatitis.

4. Ammonia/Detergent Mixture Commercial glass/mirror cleaner consists of a mixture of ammonia, detergent, fragrance, coloring agents, etc. The ammonia is the hazardous component, and is classed as moderately toxic with skin toxicity. Although the ammonia is fairly dilute in formulations of this type, the cleaner is somewhat irritating and corrosive to body tissues and excessive inhalation will irritate the mucous membranes. Contact of ammonia (i.e., ammonium hydroxide) with chlorine or chlorine bleach will generate chloramine gas. Ammonia is also incompatible with acids.

Since all of these chemicals can be harmful, depending on how they are used and the degree of exposure, handling must be done in accordance with established methods to prevent unacceptable exposures. In general the handling methods are identified to personnel by training and in the procedures. The necessary protective equipment (respirators, face shields, safety showers and eyewash stations, etc.), and clothing (gloves, apron, acid suit, etc.) and the appropriate firefighting methods are identified.

5.3.2 Fire and Explosion Safety

The CPP-603 underwater fuel storage area was designed for some loading with flammable materials. The building structure consists of concrete, structural steel and Transite, an asbestos siding material. Sources of flammable materials in the facility include transport vehicles (fuel and rubber tires), as well materials used in contamination control, e.g., paper, plastic sheeting and bags, rags, Anti-C clothing, etc. In addition lubricants, wood pallets, tarps and hoses are also flammable. The facility and the stored fuel are not flammable.

A fire protection program and policy[37] have been developed at the ICPP to establish a level of fire protection adequate to control fire loss to acceptable levels. The policy specifies the objectives of the program regarding the maximum effects of the fire (to life, off-site, and property damage). The policy identifies the responsibilities of the departments, the Emergency Response Team and common hazards. In addition

to this policy, fire-fighting restrictions have been developed with respect to criticality safety in fissile material storage areas. In this case the stored fissile material is already fully flooded and there are no restrictions on the use of water for fire fighting. This portion of CPP-603 is Code I area, since there is a low probability of a criticality resulting from fire-fighting efforts.[8]

All buildings at the ICPP are equipped with portable fire extinguishers, and major buildings are also equipped with 1-1/2-in. fire hoses. All ICPP fire alarms are connected directly to the DOE Fire Department at CFA-666. CPP-603 requires a phone call to actuate the voice paging system. Water supplies for fire fighting purposes are available from the CPP-614 fire pumps, the plant industrial water supply or directly from the electric deep well pumps.[38]

At the CPP-603 underwater fuel storage facility, small fires can be controlled by using one of the 18 portable fire extinguishers or by using a fire hose connected to one of the four fire-hose cabinets, all of which are located within the facility. The fire-fighting water connection at this facility is a 6-in. riser. The ion exchange area (between the south and middle basins) is equipped with a wet pipe automatic sprinkler system, which also supplies water to the fire-hose cabinets.

Outdoor fires can be fought with water from a fire hydrant at the south end of the building. A 350-pound portable dry fire extinguisher is also available for use around the CPP-603 complex. In accordance with the fire protection policy,[37] the hazard from an outdoor fire is controlled by continuous removal of rubbish, brush, weeds and other combustibles from areas where they can become a fire hazard to any building. Herbicide treatment of surrounding soil areas keeps weeds and brush from growing.

Aside from the usual fire hazards (interior and exterior fire loading), there are a limited number of special potential fire and explosion hazards associated with this facility. As discussed in the previous section on chemical safety, nitric acid can contribute to fires when in contact with organic materials. For example, cleanup of a

nitric acid spill with paper can cause the paper to either ignite or serve to increase the flammability of the paper. Several violent reactions of oxalic acid are also cited, including the fact that it reacts explosively with chlorites or hypochlorites.

In addition to increasing flammability of organic materials, nitric acid has been involved in thermal explosions, when in contact with commercial cation resins. Nitric acid is used to regenerate the Duolite 464 resin in the VES-SF-131 ion exchanger. The other three exchangers, VES-SF-101, -102 and -132 are charged with Zeolon 900, or the PDZ-14010 material (or are empty), which are replaced with fresh material, when necessary, rather than being regenerated.

The conditions necessary for the potential explosion in an ion-exchange resin bed are a combination of high acid concentration, long exposure times and elevated temperatures. The resin used for strontium removal, Duolite 464, replaced Amberlite 200, also a cation resin regenerated by nitric acid. Compared to the Amberlite 200 resin, Duolite 464 is a high-capacity, weak cation resin that can be regenerated with comparatively dilute acid. The Duolite resin is regenerated with less than 0.5 $\underline{M}$ nitric acid. In addition to low acid concentration, the potential for an explosion is avoided by short exposure times and lack of elevated temperatures. The resin is also rinsed after the regeneration cycle to remove excess acid.

5.3.3 Personnel Health Hazards

As in any work environment, there is a potential for injury to personnel at the CPP-603 underwater fuel storage facility. The areas of chemical safety, fire/explosion safety and radiological safety have been discussed previously. Avoidance of these hazards by the appropriate control methods minimizes the possibility of injury to personnel. The additional hazards to personnel health at this facility include exposure to asbestos, herbicides and some general industrial hazards.

The herbicide exposure hazard can arise from the practice of applying herbicides to the soil surrounding the facility to prevent accumulation of combustible plant materials (grasses, weeds, etc.). The

procedures for handling and application of these materials are contained in the ICPP Industrial Safety Manual.[39] Herbicides vary greatly in toxicity, and the effects may be acute and immediate or result in delayed and/or chronic health problems.

Asbestos exposure can arise in this facility due to the presence of Transite as a construction material. Improper handling of asbestos products, including Transite, may release asbestos fibers to the air. Airborne asbestos fibers pose a health hazard when inhaled. Inhaled asbestos is a carcinogen, and can result in long-term respiratory problems and cancer in exposed individuals. Airborne asbestos has not been detected in the CPP-603 facility, although it has been found in the soil external to building and in soil deposits on the facility roof. Proper procedures for handling of asbestos products, including personnel protection measures are identified in the ICPP Industrial Safety Manual.[40]

In addition to this variety of special personnel health hazards, personnel at this facility can be injured from more mundane hazards. These hazards include electrocution, slips/falls, vehicle accidents, and accidents arising from improper use of heavy equipment (cranes, hoists, straddle carriers, forklifts). These hazards are largely mitigated by training, and proper housekeeping. Due to the presence of large bodies water in this facility, drowning is a possibility if someone falls into the water, although the facility is equipped with rails at poolside to serve as physical barrier against accidental immersion. The more immediate result of falling in the water is skin and internal (through ingestion) contamination from the basin water. Immersion in the water is avoided by use of safety harnesses. Rescue equipment is provided to prevent personnel from drowning.

5.3.4 Preventive Maintenance

At the ICPP, preventive maintenance is performed to ensure continued safe operation of equipment. Instruments are calibrated at the frequency identified for the instrument group (I, II or III). At CPP-603, vehicles and lift equipment are routinely maintained and tested. Crane cables are

replaced whenever there is any sign of fraying to ensure proper performance of the crane. The fuel handling cranes, fuel handling hoists, and the cask handling cranes, are routinely tested to demonstrate compliance with the applicable sections of the DOE Hoisting and Rigging Manual.[41] These cranes are routinely used for lifts identified as high and special-high-consequence lifts. Such lifting has the potential for causing extensive damage to the facility or severe personnel injury, if the load (e.g., a fuel shipping cask/charger) is dropped, upset or involved in a collision. As discussed in Section 5.1.4 (criticality accident discussion), properly maintained, inspected, and load-tested lifting equipment is significant in the prevention of criticality accidents that might arise from dropping of loads (e.g., fuel transfer casks).

5.4 WATER QUALITY

Basin water quality control is important to safety for several reasons. It is desirable to maintain a low corrosion rate for preservation of fuel, fuel handling equipment and facility structural integrity. It is also desirable to maintain basin water clarity for ease of fuel handling operations.

The quality of the basin water has a direct bearing on the corrosion of fuel materials and containment, including cans, buckets, and racks. Failure of the fuel containment can lead to a loss of the fuel or fuel storage geometry, which affects criticality safety in the facility. Loss of primary containment, e.g. the fuel clad or can may lead to radionuclide introduction into the basin water. The parameters of water quality that have the most effect on the corrosion are pH, heavy metal contamination, and chloride ion concentration. These parameters are monitored by routine sampling and analysis of the basin water. Algae and bacterial growth, which impact the water clarity, are monitored by routine sampling and analysis of the basin water. Increased water temperature will accelerate the rate of corrosion, therefore the temperature of the water should be maintained as low as possible.

The pH range of the basin water must be maintained between 5.0 and 8.5 to minimize the corrosion of aluminum, stainless steel and zirconium fuel materials. Generally, the pH is easily controlled within this range except after nitric acid regeneration of the Duolite 464 resin in the VES-SF-131 ion exchanger, when the pH may drop below 5.0 for a short period of time. The pH of the basin water is monitored after a regeneration cycle to permit adjustment to the minimum pH value. With nitric acid regeneration of the exchanger, it is unlikely that the pH of the water would exceed the upper value since the water is always slightly acidic. Addition of gross quantities of a base would be necessary to increase the pH to 8.5 or greater. At a water pH of 4, the oxide film on aluminum surfaces which protects the metal from corrosion begins to dissolve. After an extended period of exposure to this pH, damage may result to the underlying aluminum metal structure. Stainless steel and zirconium are not affected. In addition, near pH 4, leaching of fission products contained in the sludge on the basin floor would occur.

Localized corrosion of aluminum surfaces is promoted by traces of copper, lead, tin, nickel and cobalt. Contamination of the basin water with these species can occur from corrosion of equipment containing them. The metal ion, after reduction from the basin water, can deposit on aluminum surfaces as small particles of the pure heavy metal. The particles act as a cathode and can cause pitting attack of the aluminum surface. Copper and mercury are particularly aggressive with respect to this type of damage. Although this problem is mitigated by prohibiting introduction of these metals or their salts into the basin water, an absolute ban is not possible, since many of the metals are incorporated into alloys (e.g., nickel in stainless steels), used as shielding material (lead in casks although coated with steel), and present as activation products.

Chloride ion concentration is an important corrosivity parameter. The effect of the chloride is enhanced in acidic solutions such as basin water. Maintaining the chloride ion concentration at 50 ppm or less, assuming that the pH is in the desired range, and a minimum nitrate to chloride ratio will minimize corrosion of aluminum by chloride. It is

believed that chloride causes breakdown of the oxide film on aluminum by intrusion into the film which leads to pit initiation at the metal surface.

Chloride ion also promotes stress corrosion cracking of stainless steel, although no problems are anticipated at the 50 ppm level at the normal basin water temperatures. By inspection of Table I, it can be seen that the chloride ion concentration was reduced to 58 ppm (August 1988) from a high of >700 ppm ten years before. With respect to aluminum corrosion, it was determined that chloride ion levels in the range of 50-75 ppm were acceptable provided that a nitrate to chloride ratio of 3-5 to 1 was maintained.[42] If the nitrate to chloride ratio is not within this range, then adjustment of the water composition by the addition of calcium nitrate is necessary to mitigate the effects of the chloride ion. The use of calcium nitrate for this purpose may result in a slight increase in the frequency of regeneration of the ion-exchange resins.[42] Although the quality of the basin water has greatly improved with respect to Cl^- ion concentration, it is a corrosive environment for susceptible materials, such as aluminum metal. Corrosion inspections are performed to monitor the continued deterioration of these materials at the CPP-603 facility.

5.5 CORROSION INSPECTION

In addition to controlling the water quality as discussed in the previous section, corrosion inspections are necessary to discover and monitor corrosion problems as they develop in the basin storage equipment and fuel. The various inspection activities include the following:

- Visual inspection of a representative number of aluminum fuel cans, including samples representative of the various lengths of time in storage, annually.

- If fuel is to be stored on the monorail system, a visual inspection of the monorail system, hangers, and storage buckets is required prior to use.

- If fuel is stored on the monorail system, a visual inspection of the monorail system is performed on a quarterly basis to detect dropped buckets.

- Semiannual inspection of the stainless steel coupons in the South Basin to determine if corrosion of the RK-SF-900 stainless steel racks or stainless steel coupons is a concern.

- Biannual (every two years) visual inspection of RK-SF-901 aluminum racks that contain fuel.

- Annual visual inspection of a representative number of criticality control fixtures used to separate fuel in a rack storage port.

- Development of a corrosion inspection program for any new racks placed in south basin service.

A corrosion inspection frequency is to be established for all new rack designs prior to placing a new design into underwater service at CPP-603. Since the use of the CPP-603 underwater fuel storage facility is expected to decline due to the availability of the CPP-666 FSA and the desire to decommission the CPP-603 facility, new rack designs are not likely to be developed for service at CPP-603.

If fuel storage is required beyond December 31, 2000, the corrosion inspection program will be reviewed before December 31, 2000, to determine if changes are needed.

5.6 POSTULATED ABNORMAL OCCURRENCES

The postulated abnormal occurrences for the operation of the CPP-603 underwater facility are summarized in Table VII. Many of these specific occurrences have been discussed in the previous subsections for the various safety topics. The items in which a potential criticality or change in reactivity are identified as the possible consequences have been developed as criticality accident scenarios in Section 5.1.4 and in Table VI.

Table VII. Postulated Abnormal Occurrences

Operation	Occurrence	Cause	Normal Prevention — Primary Safeguard	Normal Prevention — Secondary Safeguard	Possible Consequences
Cask/charger handling	Fuel falls out of cask/charger top or bottom	Equipment or procedural failure leading to loss of cask/charger lid or open bottom	Performance of cask/charger handling operations by certified personnel	Administrative controls requiring securing of bottom openings and lid closure devices (if minimum critical number of fuel pieces present) for cask/charger	a) fuel spill in water, potential criticality – MPA b) fuel spill in air – high radiation exposures to personnel, damage to cask/charger or impacted surface NOTE: Lid closure device requirement not a safeguard for spill in air, unless cask/charger contained minimum critical number of fuel pieces.
Cask/charge handling	Contaminated coolant drained to basin water	Failure to follow procedures	Sampling and analysis of coolant required	Backflushing of contaminated coolant to hot waste tank required	Temporary/local increase in radionuclide levels in basin water
Cask/charge handling	Contained fuel is overheated	Loss of coolant mechanism or excess heat flux	Presence of coolant mechanism – liquid or air – required (e.g., draining of coolant rather than backflushing with alternate liquid)	Excess heat flux – violation of requirement at shipper's end Cask/charger handling	Radiation exposure, release of fission products to air of basin water
Cask/charger handling	Interior of cask/charger pressurized	Overheating of cask contents	Presence of coolant mechanism – liquid or air – required (e.g., draining of coolant rather than backflushing with alternate liquid)	Venting through HEPA filter	Radiation exposure, release of fission products to air or basin water (Note: Overheated fuel and overpressurized cask/charger interior probably not separate occurrences)
Cask/charger handling	Cask/charger impact on fuel piece	Failure to follow procedures	Performance of cask/charger handling operations by certified personnel	Administrative control requiring inspection of unloading area for fuel prior to placement of cask/charger in area	Fuel damage, possible fission product release to basin water and potential criticality
Cask/charge handling	Fuel-loaded cask/charger, lid removed, brought too close to water surface	Failure to follow procedures	Cask/charger handling procedures	Surveillance of operation by a health physics technician	Radiation exposure to personnel

Table VII. (Contd.) Postulated Abnormal Occurrences

Operation	Occurrence	Cause	Normal Prevention		Possible Consequences
			Primary Safeguard	Secondary Safeguard	
Cask/charger handling	Cask lid handling mechanism (north transfer station) falls under weight of entire cask	Failure to remove cask lid bolts prior to placing in the water	Cask/charger handling procedures		Cask lid retaining mechanism not intended to bear entire weight of cask, and probably weakened by corrosion (carbon steel construction); destruction of this equipment, and cask damage, and long-term downtime.
Fuel handling	Fuel handling operator falls into basin water	Operator error or failure of safety equipment	Safety equipment (harnesses, etc.) provided	Use of safety equipment by personnel required in the procedures,	External contamination from basin water, possible internal contamination if water ingested, potential fatality from drowning
Fuel handling	Fuel piece dropped or placed on top of fuel storage rack	Operator error or equipment failure	Fuel handling procedures	Preventive maintenance of fuel handling equipment	Fuel or rack damage (drop situation), potential increase in rack array reactivity due to contribution from fuel on top of rack
Fuel handling	Fuel dropped onto basin floor	Operator error or equipment failure	Fuel handling procedures	Preventive maintenance of fuel handling equipment	Potential fuel damage, operating schedule delay
Fuel handling	Fuel placed against side of rack	Operator error	Fuel handling procedures	Preformance of fuel handling operations by certified personnel	Potential increase in reactivity of rack storage array if rack is RK-SF-900 design
Fuel handling	Fuel stored in incorrect storage location	Operator error or incorrect storage location designated in instructions	Approved fuel listing identifies approved locations	Instructions double-checked	Potential increase in array reactivity or criticality; loss of inventory control due to misplaced fuels
Fuel storage	Loss of fuel containment	Receipt of damaged fuel, or deterioration subsequent to storage due to corrosion mechanism	Evaluation of fuel integrity prior to storage	Water quality control and corrosion inspections	Radionuclide release to basin water, faster accumulation of radionuclides in ion exchange systems
Fuel storage	Fuel deterioration	Deterioration due to corrosion mechanism, exceeding storage life of fuel	Determination of fuel storage life prior to receipt	Repackaging of fuel, or removal from basin (e.g., fuel processing headend of final disposal)	Loss of fuel structure, possible loss of small fueled pieces components (into sludge layer on basin floor), potential reactivity effects from altered fuel structure

Table VII. (Contd.) Postulated Abnormal Occurrences

Operation	Occurrence	Cause	Normal Prevention		Possible Consequences
			Primary Safeguard	Secondary Safeguard	
Fuel storage	Release of fuel storage bucket from monorail hanger	Equipment failure – bucket/hanger connection	Preventive maintenance of storage equipment	Bucket/hanger combinations designed and selected to avoid dissimilar metal couplings and incorporate corrosion allowance	Operating schedule delay (potentially reactivity effects, criticality a factor after more than one bucket drops off hanger)
Fuel storage	Loss of basin water	Failure of facility to contain water – due to loss of integrity of aging facility or major damage from external force, e.g., earthquake	Facility inspection and routine maintenance	Water replacement from external sources (fire-water loop, etc.)	Loss of shielding (high direct radiation fields), potential nuclear reactivity increase, contamination of surrounding environment by released basin water and any subsequent fission product release from fuels
Fuel storage	Floating fuel container	Container becomes buoyant due to gas evolution (corrosion or reaction of water w/Na, Nak, etc.)	Negative buoyancy incorporated into fuel/container assembly	Water quality control corrosion inspections	Radiation exposure, operating schedule delay due to recovery operations
Ion exchange regeneration	Resin bed explosion	Improper operating conditions used during nitric acid regeneration of resin	Duolite 464 resin regeneration requires very low acid concentration; controlled by makeup procedures	Other necessary conditions are high temperature, and long exposure times.	Damage to ion exchange vessel, room, release of fission products to facility, potential for personnel injury, extensive down-time for ion exchange system and long-term impact on basin water contamination
Chemical handling	Personnel exposure or injury	Failure to follow procedures	Chemical handling done by personnel trained in safe handling methods	Chemical hazards, handling methods, safety equipment, etc. specified by industrial safety experts	Depending on the chemical involved, reversible or irreversible injury or damage to affected personnel.

5.7 ENVIRONMENTAL CONSIDERATIONS AND NATURAL PHENOMENA

The hazards to the environment arising from operation of the CPP-603 underwater fuel storage facility, and the effects of natural phenomena on the facility are discussed in this section.

5.7.1 Hazards to the Environment

The potential hazards to the environment from operation of the CPP-603 underwater fuel storage facility include radiological releases and asbestos. The airborne radiological release is discussed in terms of exposures, both on- and off-site, in Section 6.0. Loss of basin water due to failure of the CPP-603 basin structure could result in the flow of radionuclide contaminants into the surrounding soil. This effect is discussed further in Section 5.5.2, since loss of basin water is considered most likely to arise from the inability of the facility to withstand a seismic event.

The potential exists for local soil contamination from asbestos, since the exterior of the CPP-603 structure is constructed of Transite, an asbestos cement board product. Cutting, drilling or otherwise abrading this material will release asbestos fibers. In this application, the Transite is being constantly abraded by windborne particles (e.g., sand), and it is likely that the soil in the immediate vicinity of the building is contaminated with asbestos fibers. Dispersion of the fibers through the air for deposition at long distances from this source may or may not be a problem. At any rate, the presence of the asbestos fibers in the soil causes excavation or disturbance of the soil to be a more hazardous operation than it would otherwise have been. In addition, there is also some localized radionuclide contamination in the soil around the building and in pockets on the facility roof. The presence of asbestos and contamination complicates the disposal of such soil to waste facilities since it could be a mixed hazardous waste.

5.7.2 Effects of Postulated Natural Events

The postulated abnormal events and their effects, discussed in this section include earthquake, prairie fire, flood and tornado.

5.7.2.1 Earthquake. Two studies have been done to assess the CPP-603 facility structure with respect to seismic resistance. Stress calculations completed on the CPP-603 structure in 1971,[44] indicated that the east-west oriented walls of the basins would fail from a peak ground acceleration of 0.295 g (earthquake equivalent to the 1940 El Centro earthquake, applied at ground surface). It was recommended that the top center points of these walls be anchored to prevent deflections of the walls towards their water side. It was also recommended that the structural members used as the anchors be designed to resist a maximum load of 40,500 pounds.[44] These modifications would increase the strength of the walls sufficient to withstand peak ground acceleration. As shown in a design drawing of the facility,[45] these modifications were accomplished between 1973 and 1975. The basin walls are tied together with steel cables. Outside walls that could not be tied to another wall are fastened by steel cable to concrete deadmen, buried in the gravel.

The seismic resistance of the CPP-603 facility was examined again in 1976.[46] Based on this later study, it was concluded that basin walls and floor are significantly overstressed for a "safe shutdown earthquake;" the walls will probably crack and leak, but not fall in.[47] In this study the peak ground acceleration of the 1940 El Centro earthquake was input at bedrock, not at ground level, and much higher calculated stresses to the facility were determined as compared with the 1971 study. In light of these later results, installation of the recommended anchoring system was probably insufficient to provide adequate protection.

The effect of the design basis earthquake on the building is not known. At the time of ICPP construction, INEEL was classed a Zone 2 earthquake region. The seismic design criteria of the structure are not retrievable; however, other buildings built at that time (early 1950's) were built to UBC Lateral Bracing criteria. These requirements are designed to protect lives and not necessarily property.[47]

The most recent seismic event of significance in this area was an earthquake registering 7.3 on the Richter magnitude scale in October 1983. This was the largest earthquake to occur in the contiguous United States since the Hebgen Lake earthquake (7.1 on the Richter scale) in 1959. During the 1983 earthquake, the peak accelerations from the closest strong-motion accelerograph at the ICPP (located on the ground floor of CPP-601) ranged from 0.034 to 0.068 g for the three orthogonal components.[48] Although considerable damage was done to property in the towns of Challis and Mackay (30-60 miles to the north-northwest of the ICPP), no structural or safety-related damage was experienced at any of the INEEL facilities.[48]

In the case of the CPP-603 underwater fuel storage facility, the extent of damage which might result from an earthquake of DBE intensity is not known. As stated previously, failure of the walls/floor is likely and fairly rapid loss of basin water could result. On the one hand, the gravel underlying and surrounding the basin may shift and migrate into the cracks or fissures in the earth to restrict the flow of water from the basin. It is more likely that the gravels would provide channels through which water might flow more easily. The shifting gravels could possibly dislodge fine material around the cracks and fissures, again providing an easier flow path. On the other hand leakage of the basin water into the surrounding soil could be fairly slow since flow into the soil is governed by the hydraulic conductivity. The seismic event is also likely to disable sources of replacement water, and severe loss of basin water without immediate recovery may be possible.

Assuming that the recovery using alternate water sources is inadequate to maintain the water level, the building gamma alarms would signal unsafe radiation levels, and evacuation of the facility would be necessary when the level drops to within about 7 feet of the top of the stored fuel. Criticality calculations were performed to assess the reactivity effects of basin water loss on the stored fuel array (see Section 5.1.3). It was concluded that criticality was not a problem, except for the TORY-IIA fuel stored in a RK-SF-901 aluminum rack. Redistribution of the fuel array through the rack is necessary

(and was accomplished during August 1988) for the k_{eff} values of the rack to be less than 0.95 for the worst-case wet fuel and dry basin situation.

The thermal effects of a basin-draining accident on a stored fuel array was also considered. It was postulated that this "loss of coolant" scenario could result in fuel overheating, with cladding failure and subsequent release of fission product gases for ATR fuel elements stored in a close-packed array in south basin aluminum racks. It was concluded[49] from reviews of thermal analyses on ATR fuel arrays that natural convection heat transfer in air would provide adequate cooling of ATR fuel elements with a decay heat output of 634 watts. ATR fuel is not shipped to the ICPP until the decay heat output is 634 watts or less.

The radiological effect of releasing up to 1.5 million gallons of contaminated basin water to the subsoil is highly speculative. The water would probably flow to the perched water layers (water in large pockets above the level of the main aquifer). Studies of the ion-exchange properties of the soil underlying the ICPP have been conducted to evaluate the migration of acidic waste solution from the high-level liquid waste storage tanks at ICPP. These studies indicate that both acidic and alkaline water would be neutralized by the time the water has traveled through 60 ft of soil. Greater than 90% of all fission products would be deposited in the soil within about 4 ft of the point where the water becomes neutralized. Nearly all the remaining 10% of the fission products should be deposited before the solution reached the perched water system. Any fission products that reach the water would be diluted to undetectable levels before reaching the INEEL boundary.

Aside from the effects due to failure of the basin structure (loss of water with potential criticality, thermal and radiological contamination as the consequences), the effect of an earthquake on other portions of the facility was considered. An earthquake with sufficient intensity to damage the facility superstructure could cause failure of the crane support bridges. A crane in some stage of loading or unloading a cask at the time of an earthquake could be dropped, contributing to basin floor cracks. Likewise, an operator on the crane bridge over the basin at the time of an earthquake may fall into the water as a result of

structural failure of the crane or severe shaking. Dropping of the south crane into the south unloading pool would have no consequences, unless it impacted a fuel unit.

In the north and middle basins, it is possible that the monorail system may detach from the top of the facility. If fuel is stored on the monorail system, criticality is a potential consequence due to loss of isolation between fuel units. The size of the earthquake necessary to severely damage the monorail system and the modes of failure have not been determined.

5.7.2.2 <u>Prairie Fire</u>. A fire in the grass and sagebrush outside the ICPP perimeter is especially possible during the peak of the fire season. A fire hydrant provides the capability to extinguish an outside fire within reach of the hose. The INEEL Fire Department can respond to ICPP within approximately 8 minutes to extinguish a blaze. The effects of a fire are mitigated because the areas inside the perimeter fence are treated with a herbicide to prevent weeds and grass from growing. The corrugated Transite siding and roofing on the CPP-603 building are noncombustible.

5.7.2.3 <u>Flood</u>. The potential for flooding the ICPP area was evaluated in 1973,[50] and later in 1986.[51] According to the 1973 study, a flood would be mitigated by several man-made and naturally occurring features. One man-made feature, the Mackay dam, has a holding capacity of 45,910 acre-ft. Flood-diversion facilities have been constructed on the INEEL to divert potential floodwaters to four dispersion areas for holding and infiltration. Natural regulation is probably the most important flood-mitigating feature in the drainage areas that are higher than the ICPP elevation.

Various cases have been postulated as causes of a flood at ICPP. In the 1973 study, the results of the flood evaluation show that the maximum predicted flood would theoretically be only about 35,000 cfs, and would bring floodwaters to the grade elevation of CPP-601/602, 4,917 ft above mean sea level (MSL). It would require a flood in excess of 80,000 cfs to raise the flood crest an additional foot (to 4,918 ft MSL), which

would be up to the level of the door of the CPP-603 building in the south end of the area. However, according to an EG&G computer study performed in 1986,[52] the Probable Maximum Flood (PMF) peak flow rate to the Mackay Dam reservoir would be 41,000 cfs. If this inflow rate were to continue for six hours, a 0.5-foot overtopping of the dam would be achieved. It is very likely that a 0.5-foot overtopping would cause this earth dam to fail. The prediction of the computer simulation DAMBRK code used in the 1986 study is that the peak flood elevation resulting from the condition described above would be 4917 feet above Mean Sea Level (MSL). Consequently, flooding inside the CPP-603 facility would not occur, since the facility grade level is 4818 feet above MSL.

5.7.2.4 <u>Tornado</u>. Tornadoes and funnel clouds at the INEEL have also been considered as a part of the safety evaluation. A tornado is defined as violently rotating column of air pendant from cumulonimbus cloud, nearly always observable as a funnel or cloud tuba. Its vortex, commonly several hundred yards in diameter, whirls, usually cyclonically, with winds estimated at 100 to more than 300 mph. When a vortex cloud reaches the surface over land, it is classified as a tornado. If the vortex does not reach the ground, it is classified as a funnel cloud.

In Idaho, tornadoes have been reported only during the warm season of April through August. In the 44 years from 1916 through 1959, 17 tornadoes were reported in Idaho while 15 were reported in the 10 years from 1960 through 1969. Improved communications and increased population are the probable reason for the increased frequency in the 1960s over the 54-year average frequency. Observational data for sightings in the vicinity of the INEEL are listed in PSD Section 2.0. During the two years prior to publication of the September 1980 version of this PSD section, five vortex clouds were sighted over the INEEL. All of them were classed as funnel clouds rather than tornadoes. However, by assuming they were tornadoes and by using this data in the probability calculation, the probability is 1.4×10^{-6}/yr that a tornado will occur at any given location over an area the size of CPP-603. This method of calculation was described by H. C. S. Thom.[53] The probable frequency of 1.4×10^{-6}/yr compares favorably with the value estimated by Fujita

$(2 \times 10^{-6}/\text{yr})$ in his review of the tornado-related atmospheric aspects of the entire Pacific Northwest.[54]

Fujita also concluded that a storm of midwestern United States severity would not be consistent with meteorological conditions in the Pacific Northwest region. A tornado in this region is expected to have a maximum rotational wind speed of about 120 mph. Tornadoes outside the Midwest would have 125 mph probable, and 175 mph maximum wind speeds, including both the rotational and the translational speeds. On the basis of these studies, a tangential windspeed of 145 mph, plus a translational speed of 30 mph, for a total of 175 mph, is considered a conservatively high estimate of potential tornado windspeed for the INEEL area. The maximum radius of the rotational wind is estimated at 150 ft. (Dr. Edwin Kessler of the National Severe Storms Laboratory in Norman, Oklahoma confirmed these maximum potential wind speed values.)

The effects and consequences of the Design Basis Tornado (DBT) with the parameters described above, on CPP-603 are purely speculative. For this discussion, the following extreme case was postulated. If a tornado demolished the steel framework and Transite siding of the CPP-603 super-structure, it is hypothesized that the high-velocity air in the vortex could entrain and remove some of the basin water. While this is theoretically possible, experts on windstorms and tornadoes estimate that a tornado could only remove from 2 to 6 ft of liquid from an open pool during passage of a funnel. The residence time over the pool would be limited to about 5 seconds if the transverse velocity of the funnel were a nominal 30 mph. The irregular perimeter of the basin would also limit the ability of a funnel to remove an appreciable percentage of the basin water. A consequence of water removal above the most radioactive fuel assemblies would be an increase in radiation above the assemblies; however, it would not be expected to exceed 40 mrem/hr if less than 6 ft of water were removed from the basin.

An additional consequence (though very improbable) may be deposition of basin water, commingling with rain, in the path of the tornado (probably from southwest to northeast). Several mitigating factors exist. The storm cell would probably cover less than 200 square miles

(about a 10 x 26 mile ellipse) and be moving at a translational velocity of 30 mph. According to a report on flooding at ICPP,[50] the maximum predicted rainstorm could have an area of equal rainfall of 25 square miles within the center of the storm cell in which there was precipitation at a rate of 5 in./hr. This rate of precipitation essentially guarantees that the basin water will be dumped within 10 to 15 minutes after it is entrained (while the storm cell would still be within the INEEL boundaries). The 500,000 gal of entrained basin water would be greatly diluted by the precipitation of water vapor in the storm cell. At a rainfall rate of 5 in./hr over 25 square miles, the dilution ratio is approximately 6000 to 1.

The high permeability of the INEEL soils would allow much of the surface water to infiltrate into the earth. Since the overlying soils have an excellent capability to absorb the fission product cations, the amount of radioactive material that infiltrates to the underlying soil would be small with negligible consequences.

5.8 MAXIMUM POSTULATED ACCIDENT

In the guidelines for preparation of the Plant Safety Document (PSD) for the ICPP in PSD Section 1.0, the maximum postulated accident (MPA) concept is introduced. The MPA concept is used to evaluate the relative hazards associated with operation of an individual ICPP facility or process. The MPA is a hypothetical accident for a given operation that is technically possible but extremely unlikely and that results in the greatest potential release of radioactive material to the environment or produces the highest potential radiological exposure. The use of the MPA approach makes it unnecessary to evaluate the consequences of lesser accidents.

A sustained nuclear criticality in the storage basin is defined as the maximum postulated accident for the CPP-603 area, even though it is considered extremely unlikely. It is possible to achieve a sustained, self-regulating chain reaction in which temperature and heat transfer rates are well within the design limits for the fuel if reactivity of the fuel array is increased by the incremental addition of another fuel

assembly. If such a critical assembly were reached in the fuel storage basin (under 15 to 20 feet of water), there probably would be no effect on any CPP-603 instruments and no resulting harm.

For the purpose of this discussion it was assumed that the excess reactivity of an accidental critical assembly would be large enough to cause observable effects. In this case, the energy release would be large enough to generate steam at the fuel element surfaces. The expansive forces of the steam might disassemble the critical array without further effects. However, if the fuel were confined, fuel temperatures and/or thermal shock might result in breach of the fuel cladding. Cladding breach is assumed to occur along with steam formation or gaseous fission product release at the surface of the water which would provide the means for detection.

A criticality can be postulated by many mechanisms using any number of the large variety of fuels stored in the basin. The specific scenario chosen as the MPA is based on the maximum amount of fuel that would be involved in the accident. The criticality accident scenarios developed for this facility (see Table VI) all have sufficient contingencies identified to make their occurrence extremely unlikely.

The specific accident selected for the MPA for the CPP-603 under water fuel storage facility involves a fuel spill from the High-Load charger. It is assumed that the charger is fully loaded with ATR fuel units with the nine-position poisoned insert in-place, and the fuel falls out of the bottom of the charger when it is lifted off of the basin floor. Unconfined by the charger and insert geometry and the poison of the insert, a criticality can occur with six or more ATR assemblies provided they are in a tight, nearly cylindrical, water-flooded array. Although the minimum critical number was estimated using conservative assumptions,[23] a full load in the charger, nine units (the physical capacity of the charger insert), is probably sufficient for criticality.

It is assumed that the fuel units fall into a critical array on the basin floor. If the fuel array is physically stable, the criticality would be bounded by the expulsion of water from the array, which would

cause the system to become momentarily subcritical. As the steam and gases from the first excursion percolate away from the array, water would re-enter the system and a smaller criticality would result. This sequence of events, the cycling between criticality and subcriticality, would continue until a steady state is achieved which allows a heat production from the system to cause a two phase water density which permits a "just" critical state. The system would remain critical until physically disassembled.[43] If the original configuration were not stable, the initial excursion would cause mechanical rearrangement of the system, rendering it subcritical. In any case, rupture of the fuel cladding by the criticality is necessary for release of fission products from the accident and from previous reactor operations. Without breaching of the cladding, the radiological effect of the accident is trivial due to the shielding of the basin water.

Fission product release from the MPA would result in the escape of a considerable amount of gaseous species from the basin water; however, condensation of steam by the basin water (15 to 20 feet) would limit the release of entrained non-gaseous fission products to the atmosphere.

A summary of the radiological effects of the MPA criticality on the CPP-603 operators and the general population is presented in Section 6.0 as part of the conclusions. Section 6.0 also includes the radiological effects of the fuel spill out of the charger above water (e.g., on the loading dock), and the effect of normal operation.

6. CONCLUSIONS

The conclusions resulting from this safety analysis are presented in this section. The radiological consequences of operating this facility are discussed. The operational safety requirements and the identified residual risks which constitute the conclusions of the safety analysis for this facility are listed. Operation of the facility within the envelope defined by the operational safety requirements is safe.

6.1 RADIOLOGICAL CONSEQUENCES OF FACILITY OPERATION

As part of the conclusions to the safety analysis of the CPP-603 underwater fuel storage facility, the radiological consequences of operating the facility are presented here. The consequences due to normal day-to-day operation of the facility, and those arising from an abnormal situation are discussed. The abnormal situations include the effects of the MPA (see Section 5.8) criticality and the effects of exposure to unshielded fuel.

6.1.1 Normal Operation

During normal operation of the underwater fuel receiving, handling, and storage facility, the primary radiological consequence to operating personnel is exposure to radiation from fission products concentrated in the multimedia filters when they are backwashed. Another normal source of radiation is from fission products that have been released to the basin water (via cladding breach, can corrosion, etc.). Past experience shows that some of the dissolved fission products are deposited as a scale on the basin wall at the water line. This has also been a source of personnel exposure during normal operation; however, it has been mitigated by steam cleaning and by sandblasting and sealing with a water resistant epoxy paint, which resists the rapid accumulation of additional scale.

The background activity in the CPP-603 area (composite of the basin water and the shielded sources) results in a nominal dose of less than 10 mrem per month (per individual) to the operating personnel as of 1988. This great improvement over the 90 mrem per month (per individual) at the

end of the 1970's is due to continued improvements in the conditions at the facility and the lowered occupancy resulting from the redirection of many underwater fuel receipt activities to the new FAST Fuel Storage Area at CPP-666. Administrative limits and management controls ensure that personnel exposure does not exceed the limits of DOE Order 5480.11,[31] and the internal ICPP guidelines.[1] All operations, i.e., loading and unloading fuel from casks, are monitored by Health Physics technicians to ensure as low as reasonably achievable exposures (ALARA) to the operators. Gamma monitors adjacent to the working areas give instant warning if radiation levels rise excessively.

6.1.2 Abnormal Operation

The radiological effects of abnormal operation discussed in this section are those due to unshielded fuel and the MPA criticality.

6.1.2.1 Exposure to Unshielded Fuel.
The exposure of personnel to unshielded fuel assemblies spilled on the concrete floor of the transfer station would be an extremely serious occurrence. This event results from a serious equipment failure or procedural error. Calculations were performed assuming nine ATR fuel assemblies were spilled near operating personnel. Figure 36 depicts the radiation dose vs. distance, assuming a slab source. The cumulative exposure would depend on the time required for an operator to retreat to a place where a suitable shield (or distance) is imposed between himself and the source. However, if the operator ran away from the source (initial distance of 2 meters) to reduce exposure, the cumulative dose was calculated to be 14 rem.

A smaller radiation exposure occurrence has also been evaluated. It assumes that three ATR assemblies accidentally fall from the bottom of the charger into the basin. In this event, the exposure is limited to the time required for the three assemblies to fall into the basin and sink into the water, where they would be shielded. It is assumed the slide drawer would not be operated beyond the point where the three
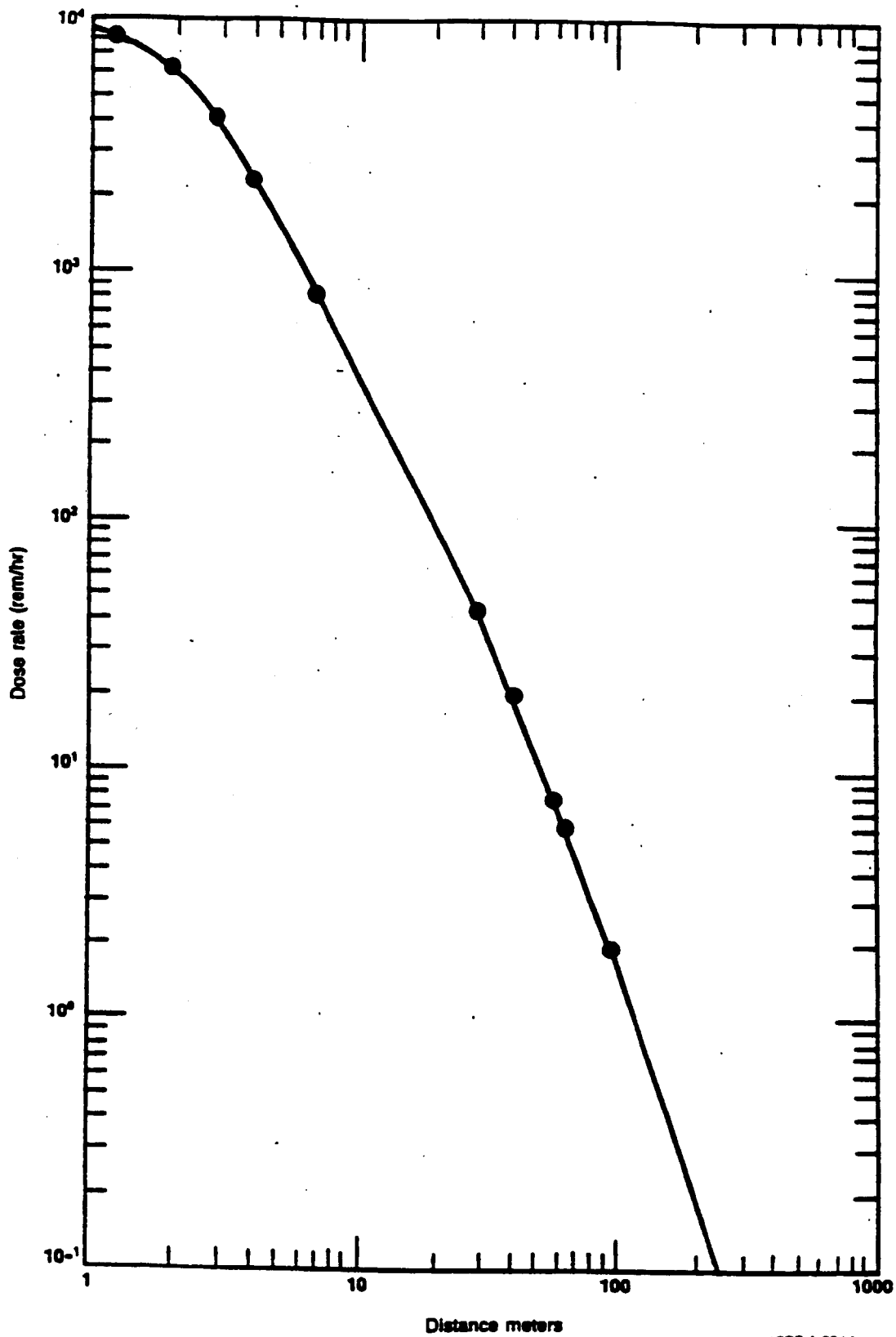
Figure 36.   Dose Rate as a Function of Distance for Slab Source of
             Unshielded ATR Fuel Elements

assemblies fell into the basin. If a person were standing 3 feet in front of the cask when the assemblies traverse the air gap from the cask to the water, the computed dose would be 4 rem (assuming one-third of the source at 1 meter and about 5 seconds exposure time).

6.1.2.2 Radiological Effects of MPA. The radiological consequences of an underwater criticality (the maximum postulated accident) at this facility have been evaluated. A criticality occurring by some other mechanism would have similar consequences, using the same types of assumptions in the calculation. The radiological effects of this postulated criticality are calculated based on the interaction of nine ATR assemblies, although the normal load in the High-Load charger is limited to eight assemblies. ATR assemblies were chosen since they represent a fuel with a high burnup, thus a high inventory of fission products. The excursion is based on the following additional assumptions:

(1) A fission spike yield of 3×10^{18} fissions.

(2) An ATR assembly weighs about 16.6 lb in air after the end boxes have been removed.

(3) Maximum metal temperature (T_{max}) in the array of ATR assemblies is assumed as $2 \times T_{avg}$. T_{max} occurs in the middle section of the center. T_{avg} is determined based on a homogeneous distribution of the fission energy throughout the whole array.

(4) Water in the array of nine assemblies is vaporized and expelled, removing 60.3 lb of water, having a sensible heat of 160 Btu/lb and latent heat of 970 Btu/lb. Some steam may be superheated; however, this was not considered in the calculations.

The consequences of this postulated occurrence are reported in terms of the dose both to the operating personnel in CPP-603 at the time of the criticality and to an off-site receptor at the nearest INEEL boundary. The exposure of an off-site receptor to the postulated radioactive cloud is based on the following assumptions:

(1) CPP-603 has no forced ventilation; therefore, it is assumed that the roll-up doors are wide open and that the radioactive cloud is released immediately at ground level.

(2) The ATR fuel assemblies have an assumed 120-day cooling period after discharge from the reactor. This fission product distribution is derived from RSAC-3S computer code and based on a percent average burnup of the U-235.

(3) The fission products in the nine-assembly array are assumed to distribute into the water and, subsequently, into the air in the following proportions:

   (a) Ten percent of the cladding is breached by the melting conditions caused by the excursion.

   (b) Twenty-five percent of the exposed fuel alloy releases all of the noble gases and halogens to the water and 10% of the other solid fission products.

   (c) Of the noble gases released to the water, 100% are released to the air.

   (d) Of the halogens released to the water (defined by Regulatory Guide 1.25), 4.7% are released to the air above the water. Four percent of the halogens are an organic molecular species; 96% of the halogens are an inorganic species. The partition factor (p.f.) (ratio of amount of isotope entering water to amount leaving water) for organic species in water is 1; the p.f. for inorganic species in basin water is 133.

   (e) Of the solid fission products released to the water, 0.5% are released to the air (p.f. of 200 for the transfer through the water).

(4) Wind velocity of 2 m/sec toward the nearest INEEL boundary.

(5) Class F meteorological conditions.

The dose to a recipient at the nearest INEEL boundary (1.35×10^4 m from CPP-603) was calculated. The recipient would receive an inhalation exposure of 0.002 rem (whole body), 0.005 rem (thyroid), 0.007 rem (bone surface), and 0.13 rem (lung) if he remained in the path of the plume for the total time of its passage.[55] The committed effective dose equivalent (CEDE) for the three organs is 0.016 rem and the penetrating dose equivalent (DE) is 0.00009 rem. Therefore, the total dose (CEDE plus penetrating DE) is 0.016 rem.

The evaluations show that the MPA results in doses to an individual at the site boundary that are within the DOE 6430.1A guideline doses. It should be noted that these guideline doses are not intended to imply that these doses constitute acceptable limits for emergency doses to the

public under accident conditions. Rather, these doses are reference values that can be used in the evaluation of facility design and site evaluation with respect to potential accidents with exceedingly low probability of occurrence and hence low risk of public exposure to radiation.

In addition, the risk of an individual at the INEEL site boundary receiving the doses listed is even lower due to the remote location of the INEEL in relationship to population centers. Plus, the fact that the highways and roads on the INEEL are patrolled by security forces, and traffic can be interrupted during emergency situations.

Another consideration of this postulated occurrence is the exposure of the operations personnel in the area to the fission products released during the excursion. In evaluating the exposure to operations personnel, the following conservative assumptions are made: (1) the roll-up doors at the ends of the building are closed, (2) the fission products are uniformly dispersed in the building air (the building has an estimated volume of 3.7×10^5 cu ft), and the personnel evacuate the building within 1 minute. Based upon a 2 minute stay time in the CPP-603 area, personnel would receive a calculated dose of 0.8 rem (whole body), 2.0 rem (thyroid), 28 rem (bone surface), and 50 rem (lung).[55] The CEDE or the three organs is 6.1 rem and the penetrating DE is 0.03 rem. Therefore, the total dose (CEDE plus penetrating DE) is 6.1 rem. One minute is assumed to be the time necessary for an operator on the bridge crane to move to the edge of the basin and leave the building, thus the doses to personnel would be half of the 2-minute stay time doses. Other personnel would normally be evacuated in 30 sec or less, upon hearing the radiation alarm. The results show that the MPA-caused doses to personnel that are below the DOE 5480.11 occupational limits, if they evacuate within one minute.

6.2 PROVISIONS FOR OPERATIONAL SAFETY

As a result of the safety evaluation included in this PSD section, certain design features and administrative controls, collectively referred to as the operational safety requirements, are essential to the integrity of the safety envelope. The design features (geometry, materials, strength, etc.), i.e., safety structures, systems, and components (SSCs), are those facility SSCs that are necessary for the facility to satisfy evaluation guidelines, provide defense in depth, or contribute to worker safety. Department of Energy standard DOE-STD-3009-94, "Preparation Guide for U.S. Department of Energy NonReactor Nuclear Facility Safety Analysis Reports" is followed as a guide to the definitions provided in the following sections. The safety envelope is also formed by the administrative controls defined for operations in this facility. These administrative controls are carried over into the Technical Standards. A list of "other" administrative controls is also provided.

6.2.1 Operational Safety Requirements

6.2.1.1 Safety-Class Structures, Systems, and Components.
DOE-STD-3009-94 defines a safety-class SSC as a system, structure, or component for which the preventive or mitigative function is necessary to keep hazardous material exposure to the public below the off-site evaluation guidelines. Section 6.1 concludes that the consequences of the CPP-603 accidents evaluated would not exceed off-site evaluation guidelines. Therefore, there are no safety-class SSCs for CPP-603.

6.2.1.2 Safety-Significant Structures, Systems, and Components.
DOE-STD-3009-94 defines a safety-significant SSC as structure, system, and component not designated as safety-class SSC but for which the preventive or mitigative function is "a major contributor to defense in depth (i.e., prevention of uncontrolled material releases) and/or worker safety as determined from hazard analysis." A worker safety SSC is further defined as an SSC for which the failure is estimated to result in "an acute worker fatality or serious injuries to workers." The standard defines serious injuries as injuries requiring "medical treatment for immediately life-threatening or permanently disabling injuries

(e.g., loss of eye, loss of limb) from other than standard industrial hazards." The standard specifically excludes potential latent effects (e.g., potential carcinogenic effects of radiological exposure or uptake).

The following is a list of each of the safety-significant SSCs for CPP-603. Some equipment for the monorail storage system has been classified as safety significant to envelop potential fuel handling and storage contingencies if fuel is found on the basin floor during D&D.

1. Pool Water Depth. The water depth and volume in the CPP-603 basins provide for shielding from radioactive fuel and for heat dissipation from the fuel decay heat generation.

2. Lateral Shielding. The facility design provides lateral shielding since all but three feet of the basins are below ground.

3. Cubicle Shielding. The cubicles in which the ion-exchange systems (old and new) are located provide shielding around the exchanger vessels.

4. Water Mark on Fuel Handling Tools. Fuel handling tool design incorporates extended-reach handles and a minimum water surface to top of fuel depth (6 feet) mark allows fuel handling with a sufficient water depth (for shielding) over the fuel.

5. Concrete Dividers. The concrete dividers are only safety significant when fuel is being stored or handled on the monorail system. The 12-in. thick concrete dividers separate adjacent monorail rows and isolate fuel in adjacent rows in the north and middle basins.

6. Monorail Hangers. The monorail hangers are only safety significant when fuel is being stored or handled on the monorail system. Monorail hanger and hanger design supports fuel between concrete and maintains safe spacing by incorporating bumpers at the track level and on the hanger shaft which provide at least an 18-in. center-to-center spacing between adjacent fuel storage positions in the same monorail row (provided that compatible hangers are used).

7. RK-SF-901 Storage Racks. The geometry of the storage array of RK-SF-901 aluminum fuel storage racks enhances criticality safety in the stored fuel array. In addition the 8-in. lip around the RK-SF-901 rack edge causes each individual rack to become an isolated array, even in an array of racks.

8. RK-SF-900 Storage Racks. The RK-SF-900 rack design provides sufficient interstitial spacing between adjacent storage positions that the interactive reactivity does not increase the

k_{eff} by more than 3.2%. This is also true for the rack positions in an infinite x-y array of these racks. The 4-in. lip around the RK-SF-900 rack edge results in an 8-in. edge-to-edge spacing between positions on the rack perimeter for an array of like racks.

9. **Criticality Alarm System.** The CAS is installed in the facility to monitor and alarm if high radiation levels are detected. The CAS detectors have a dual function, criticality accident detection and a RAM function.

10. **Duolite 464 Ion-Exchange Resin.** The use of Duolite 464 as the ion-exchange resin for strontium removal, rather than Amberlite 200, allows the use of very dilute nitric acid for regeneration, which minimizes the potential explosion hazard identified for such operations.

11. **Criticality Control Fixture.** Criticality control fixtures are safety significant when they are used to separate fuel in a storage port as designated in the approved fuels list in Technical Standard 4.6A1. The criticality control fixtures physically prevent fuel on multiple tiers (typically 2 tiers) from being placed side-by-side.

12. **Cask and Fuel Transfer Cranes and Rigging.** The cranes are equipped with numerous safety features, including redundant brakes and safety shutdown mode. The large-capacity cranes (15- and 60-ton) do not travel over the fuel storage basins. The auxiliary equipment (hooks, slings chains and load bars) are designed with a 5-times the load safety factor.

6.2.1.3 <u>Administrative Controls.</u> These controls include the administrative controls specifically identified in the criticality accident scenarios as barriers, as well as those controls identified, either implicitly or explicitly elsewhere in this PSD section.

1. Prior to receipt of proposed fuel shipments, sufficient fuel data (generally supplied in the form of a response from the shipper to the Fuel Receipt Criteria questionnaire) is required to allow a criticality safety evaluation and a review to determine materials compatibility between the facility and the proposed fuel storage operation.

2. An accountability/inventory system that documents fuel type, component/core identity, fissile loading (as per shipper's values), and storage location in the CPP-603 underwater fuel storage facility must be provided and maintained current.

3. Removal of the lid from any fuel-loaded cask/charger is not permitted unless the top of the cask/charger is shielded by at least six feet of water.

4. The lifting equipment at the CPP-603 underwater fuel storage facility used for high-consequence and special high-consequence

lifts (CRN-SF-35, -301, -001) must be tested and inspected in accordance with the requirements of the DOE Hoisting and Rigging Manual. Testing and inspection of lifting equipment and auxiliary items is required for that equipment in which loss of the load has potential consequences that meet the criteria of PSD Section 15 (e.g., potential criticality, excessive radiation exposure to personnel, facility damage, etc).

5. The instruments designated as Group I for this facility must be operable as follows:

   - four of the five CAS monitors must be operable when a fuel transfer operation is initiated (an operation in progress may be completed if less than four detectors are operable), with CAS-SF-51 and -52 among the four monitors for operations in the north transfer station, and with CAS-SF-55 one of the four monitors for operations in the south transfer station

   - five of the eight CAMs located in the facility must be operable; if less than five are available then all fuel handling operations, except those at the transfer stations must cease until sufficient CAMs are available (either by repair or replacement)

   - the water level instrument must be operable whenever the facility contains fuel; if the instrument becomes inoperable, repair or replacement must be completed within 24 hours, or the system water level monitored hourly by an alternate method.

6. Storage of fuels in the CPP-603 underwater fuel storage facility is limited to the types and configurations approved by ICPP contractor management and DOE-ID.

7. The following parameters must be met for fuel stored in the RK-SF-900 stainless steel racks:

   - 8-in. water gap between the top of the fuel and the top of the rack

   - 8-in. water gap between fuel-containing positions of the RK-SF-900 rack and fuel-containing positions of any other rack

   - single position k_{eff} must not exceed 0.88

   - fuel U-235 linear density must not exceed 5.0 kg/ft.

8. In addition to the criteria specified in Item 7 above, for the RK-SF-900 racks, the following restrictions also apply:

   - immediately after completion of a fuel loading operation into an RK-SF-900 rack position, installation of the

criticality control fixture that prevents over-batching of
the rack position is required

- only one RK-SF-900 rack lid is permitted open at any one
time, and then only for loading/unloading operations or
given supervisory approval, for inspection (of the
position contents or for training purposes); closure of
the lid promptly after the completion of the operation
requiring the opening is also required

- if the activity requiring opening of the lid also requires
removal of the criticality control fixture from the rack
position, supervisory approval must be obtained for the
removal

- the presence of the criticality control fixture must be
independently verified by a second certified person who
witnesses the installation or inspects the rack position
prior to lid closure

- closure of the rack lid must be independently verified
after each opening of the lid

- prior to transfer of fuel out of the south transfer
station for placement in a RK-SF-900 rack position, the
designated rack position is inspected to verify that the
proposed fuel configuration is in compliance with an
approved fuel storage configuration for this rack type.

9. The following requirements must be met for fuel storage in the
RK-SF-901 racks:

- 8-in. water gap between the top of the fuel and the top of
the rack

- the storage of multiple fuel pieces in a rack position is
permitted in an end-to-end configuration (not
side-by-side) provided the water gap requirement is met

- placement or storage of any non-fuel pieces in a rack
position is prohibited (effect is outside the scope of the
criticality safety evaluations)

- fuel units in which the endboxes have been removed can be
stored in these racks if the original fuel configuration
(which was the basis of the criticality safety evaluation
for storage) is maintained after the cutting

- the RK-SF-901 rack used for TORY-IIA fuel storage is
dedicated for that purpose (no other fuel type is
permitted to be placed or stored in the empty positions of
that rack) and the empty position of the rack distributed
into the fuel array in a checkerboard fashion or into a
zone between two halves of the fuel array.

10. The following requirements must be met for fuel storage on the monorail storage system in the north and middle basins:

- assembly of fuel pieces into a bucket for monorail storage must result in an approved fuel configuration and the resulting FHU must be sufficiently low in reactivity that two such FHUs have a maximum k_{eff} less than 0.95 in a water-flooded array

- single-component FHUs which are sufficiently reactive that a water-flooded array of two such FHUs has a k_{eff} of 0.95 or greater must be isolated on the monorail system in arrays of one FHU each (usually done by having empty monorail hangers in the adjacent positions on both sides of these type of FHUs)

- a minimum of 8 in. of edge-to-edge spacing must be maintained in the monorail storage rows between fissile materials stored in the individual positions; quarterly inspections of the north and middle basins are conducted to ensure that like (i.e., compatible) hangers are used in adjacent positions in the row and that unlike hangers are separated by an empty hanger/bucket.

11. Fuel handling operations must be conducted in accordance with the following restrictions:

- no more than one fuel piece is allowed out of the cask or out of the bucket when an FHU of this type (bucket storage) is being assembled

- in addition to fuel contained in a cask (located in one of the transfer stations) no more than one fuel handling unit (as defined in the approved fuel listing) is allowed out of storage at any one time in each of the storage basins, the transfer stations and the transfer canal

- if the FHU being handled is highly-reactive (such that a water-flooded array of two such FHUs has an array k_{eff} of 0.95 or greater) then no other fuel (unless contained in a cask) is permitted out of an approved storage location anywhere in the underwater portion of the facility.

12. Although the subject of cask handling is more properly treated in PSD Section 4.5, the following operating restrictions results from this analysis:

- cask/chargers must not be placed in an unloading area that already contains fuel; inspection of the area and verification that the area does not contain fuel is required

- sufficient lid closure bolts must left in place on casks/chargers handled in the south basin transfer station when the contents of the cask/charger exceed a minimum

critical mass (or number of units) for the contained fuel type.

13. The following requirements apply to structural safety of the fuel storage (some of these controls also have criticality safety implications):

    - moving or lifting a storage rack that contains fuel is prohibited

    - transfer of an empty storage rack (or any other heavy object in excess of the rack design for impact) over a rack that contains fuel is prohibited

    - only fuel handling units approved for storage in the aluminum racks are allowed to be transferred over the RK-SF-901 racks

    - only fuel handling units approved for storage in the south basin are allowed to be carried over the RK-SF-900 racks.

14. The basin water quality requirements are as follows:

    - the pH of the basin water must be maintained in the range of 5.0 to 8.5; operation outside of this range must not persist in excess of six days and action must be taken within the first 24-hour period to return the pH to the specified range

    - the chloride content of the water should not exceed 75 ppm, and the nitrate to chloride ratio should be about 3.5:1

    - introduction of exposed heavy metals, or the salts there of, of mercury, copper, lead, tin, nickel and cobalt is prohibited.

15. Corrosion inspections of the CPP-603 fuel storage equipment are conducted as follows:

    - visual inspection of a representative number of aluminum fuel cans, including samples representative of the various lengths of time in storage, annually

    - if fuel is to be stored on the monorail system, a visual inspection of the monorail system, storage buckets, and hangers is required prior to use

    - if fuel is stored on the monorail system, a visual inspection of the monorail system is performed on a quarterly basis to detect dropped buckets

    - semiannual inspection of the stainless steel coupons in the South Basin to determine if corrosion of the RK-SF-900 stainless steel racks or stainless steel fuel cans is a concern

-    biannual (every two years) visual inspection of RK-SF-901
      aluminum racks that contain fuel

-    annual visual inspection of a representative number of
      criticality control fixtures used to separate fuel in a
      rack storage port.

6.2.2 Other Safety Considerations and Features

1. Sampling of the basin water is required to monitor water
    quality. The analyses to be included are pH, nitrate,
    chloride, and other compositions of interest.

2. Continuous Air Monitors (CAMs), are installed in the facility
    to monitor and alarm if airborne radioactivity is detected.
    Permanent dosimeters are installed throughout the facility to
    provide a record of radiation levels.

3. Fire-fighting equipment, including portable extinguishers and a
    wet-pipe sprinkler system (in the ion exchange regeneration
    area), are located at the facility.

4. The facility structure consists of non-flammable materials,
    e.g., asbestos construction materials, concrete and structural
    steel.

5. Safety showers/eyewash stations are located in the area.

6. The transfer canal floor grating is covered with aluminum-clad
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7. The FECF HEPA-filter provides for safe controlled venting of
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